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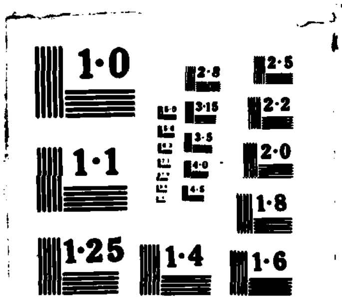
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DEPARTMENT OF DEFENCE
DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION
WEAPONS SYSTEMS RESEARCH LABORATORY
RAN RESEARCH LABORATORY

RANRL TECHNICAL MEMORANDUM (EXTERNAL) No. 21/85

REAL TIME OCEANOGRAPHIC ANALYSIS FOR THE SOUTH WESTERN AUSTRALIAN AREA FOR JULY 1984 TO AUGUST 1985 (U)

L.J. HAMILTON

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ABSTRACT

Attempts made at real time oceanographic analyses for the south-western Australian area are shown diagrammatically in the form of contour maps, ~~and~~ results ~~discussed~~. The period ~~is~~ July 1984 to August 1985. It is concluded that with present data sources, useful sea surface temperature analyses should be possible in late spring, summer, and perhaps early autumn, but not in winter, when cloud coverage severely hinders satellite data acquisition. Subsurface analyses were not possible, almost all data ~~being~~ for the sea surface.

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REAL TIME OCEANOGRAPHIC ANALYSIS FOR THE SOUTH WESTERN AUSTRALIAN AREA FOR JULY 1984 TO AUGUST 1985.

INDEX

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1. INTRODUCTION

Data for the West Australian oceanographic area 30-35°S, 110-115°E and vicinity (Fig.1) has been monitored from July 1984 to August 1985 to estimate the feasibility of setting up a real-time analysis scheme such as that presently run by the Naval Weather Centre (NWC) at Nowra for the east coast area of Australia, e.g. see Low (1984). The aim is to produce contour maps of sea surface temperature (SST), mixed layer depth (MLD), and flow patterns. A climatological (statistical) analysis was also undertaken to further knowledge of the relations between SST signature and subsurface temperature fields in the area (Hamilton, 1984 - part 1; Hamilton, 1985). Hamilton (1984) considered that real-time analyses should be possible, although the area is still not well known. This memorandum discusses the attempts made to produce such analyses and the conclusions drawn from them. Data is available from occasional merchant ship observations of SST, from naval XBT's; and from satellite infra-red imagery and derived SST values.

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2. DATA SOURCES

Absolute SST values are available by telex from the Australian Bureau of Meteorology Melbourne on a daily basis via the Global Telecommunication System (GTS). Both NOAA and GMS (Geostationary Meteorological Satellite) values can be obtained. The Western Australian Institute of Technology (WAIT) operates a receiving station for NOAA satellite data and produces near daily or weekly colour prints based on thermal emission bands (Myers, 1984). Only one colour scale is used and the images are ungridded for latitude and longitude. For July to November 1984 low resolution GMS grey scale images were also available. These are no longer obtained by RANRL.

Expendable bathy-thermograph (XBT) temperature profiles were occasionally available from naval vessels. Merchant ship observations of SST were obtained through telex as above.

These and other possible sources of data are discussed in Hamilton (1984), part II. Appendix A here gives further information such as data examples and decoding instructions for telex information. For this exercise the telex information for satellite and ship SST observations were passed on to RANRL by NWC Nowra. Fleet XBT signal information and WAIT colour images were received by RANRL directly.

3. GENERAL CIRCULATION PATTERNS

Circulation patterns are discussed in Hamilton (1984). A draft CSIRO information sheet is in preparation by Pearce and Cresswell (1984, 1985). Such information is necessary to interpret satellite imagery. A pictorial representation of general flow patterns is given in Fig. 15. Circulation may be summarized as follows:

The main feature in the area is a warm poleward boundary current which flows southward down the shelf break. This current pivots at Cape Leeuwin to flow eastwards across the Great Australian Bight. In winter (June to September) the current originates largely from low salinity high temperature water from the North West Shelf area (the seasonal Leeuwin current) and in summer from an inflow of high salinity relatively lower temperature Indian Ocean water along 30-31°S (the permanent southwards current), flowing east or north-east into the coast before turning south. Shallower seasonal shelf currents are also seen which are influenced by prevailing winds in direction, with trends north in summer, i.e. there may be no relation with seawards flow. A weak northward flow may also be present seawards to the north west of the area (the West Australian current). Cold and warm-core meso-scale eddies appear seawards, with smaller cyclonic (cold) features flanking the Leeuwin current. Deeper flow may be opposite in direction to, or bear little relation to, surface flow. The terminology used is that of Cresswell and Golding (1980).

Typical SST patterns are shown in Figs 4(b), 5(b), 7, and 8. The southward flow along the coast and a sharp front off Cape Leeuwin are probably permanent features of the area. Colder water tends to enter the area from the south-west and warmer water from the north-east (and north). The classical current pattern deduced by Andrews (1977) for the area appears as flow around the Naturaliste Plateau.

Some modelling of shelf currents has been done by Andrew and others (1983), and more work on these currents is being undertaken for the Americas Cup yacht race.

Mixed layers tend to be deeper from April to September, particularly for July to September. The unseasonally warm waters of the autumn-winter Leeuwin current are accompanied by deeper than usual mixed layer depths (Hamilton, 1985).

4. METHOD OF ANALYSIS

All SST absolute values (and MLD and sub-surface temperature values) were plotted for fortnightly periods on the one plotting sheet. Where data was sparse, monthly plots were made. If several satellite values were available for one latitude-longitude position, then all were shown, with no averaging carried out. This allowed trends to be seen, e.g. warming during a period, and made detection of bad values an easy task. It sometimes shows when fronts pass through an area. Fortnightly periods were chosen (rather than weekly) to match the temporal density of data. Patterns seen in the satellite imagery were then transcribed to the plots after a latitude-longitude grid had been drawn for the imagery. (See Appendix B for more details). An attempt was then made to draw contours of absolute SST values.

Analyses for each period were first attempted independently of previous periods, then the previous data also used. A couple of analyses use data from the first few days of next period. No back correcting of previous analyses was made.

It was anticipated that the first good analysis made could be carried over into following data scarce periods until fresh data could confirm or deny its continuing validity.

5. THE ANALYSES

The contours and patterns drawn are shown in Figures 1(a) to 14(b). A brief discussion is given opposite the figures. Overall results will be described in a following section. GOSSTCOMP SST analyses produced by NOAA are also shown. Comparisons will be discussed later in Section 6.

Abbreviations used are as follows:

BBXX - ship observations of SST

GMS - geostationary meteorological satellite observations of SST (Japan Meteorological Bureau)

I.R. - infra-red

NOAA - National Oceanic and Atmosphere Administration satellite observations of SST

WAIT - Western Australian Institute of Technology

XBT - expendable bathy-thermograph

The numbers of GMS and NOAA observations for each one degree square are shown beside the identifying symbol for each, but the absolute values are not.

Dashed contours are speculative, and dotted contours especially so. Contours drawn only from satellite imagery are not differentiated from contours drawn using absolute values.

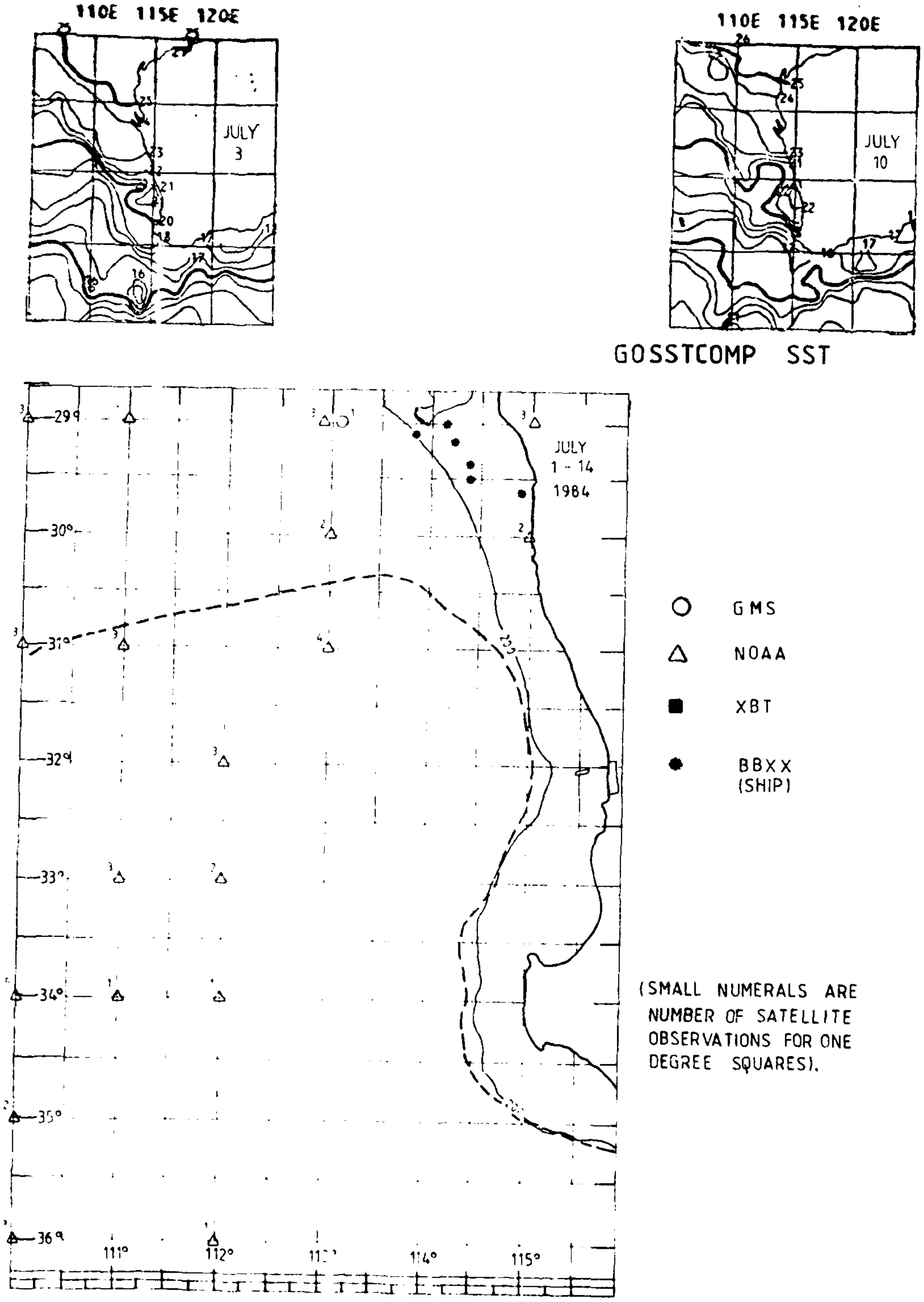

Fig. 1(a). SST Analysis for July 1-14 1984.

Period: July 1-14, 1984 (Fig.1(a))

Data

XBT	-	none
BBXX	-	6 south of Abrolhos Islands
NOAA	-	sparse coverage seawards, none within 2° longitude of land south of 30°S.
GMS	-	one value only, on 29°S
I.R. images	-	none (cloud covered)

There are no subsurface measurements.

The satellite values are not of sufficient density to draw contours. NOAA absolute values range from 22.6 to 25.6°C. The maximum SST recorded for July in 25 years of BT data for 30-35°S, 110-115°E is 22.2°C, and average 19.3°C, so all values appear too high, except for the one northern GMS value of 19.6°C. However, BBXX values north of this area are also high. The GMS value and three corresponding NOAA values differ by 5.6 to 6°C. The BBXX indicate warm water over 23°C to the north along the coast with one value at 21.5°C. A Macquarie image for 23 July suggests a coastal current from north of 30°S rounding Cape Leeuwin, but it is very faint.

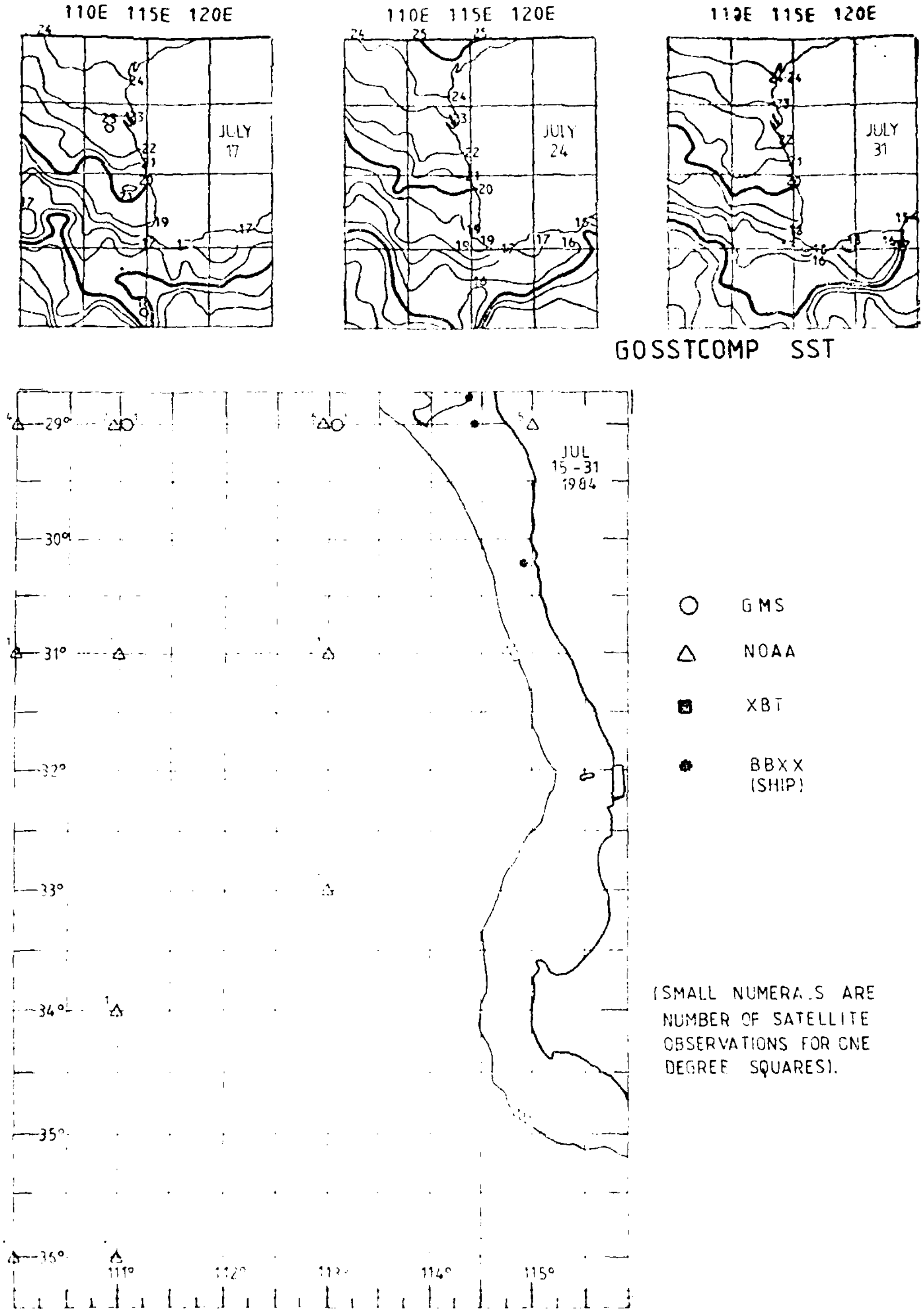

Fig. 1(b). SST Analysis for July 15-31 1984.

Period: July 15-31, 1984. (Fig.1(b))

Data

XBT	-	none
BBXX	-	three, south-east of Abrolhos
NOAA	-	sparse coverage, largely from 21, 22 July
GMS	-	two values only
I.R. images	-	none (cloud covered)

No subsurface measurements.

Remarks are similar to the previous period. BBXX differ by almost 6°C from each other. It appears that the GMS and NOAA values are incompatible data sets as they differ by up to 6°C, with NOAA values being too high.

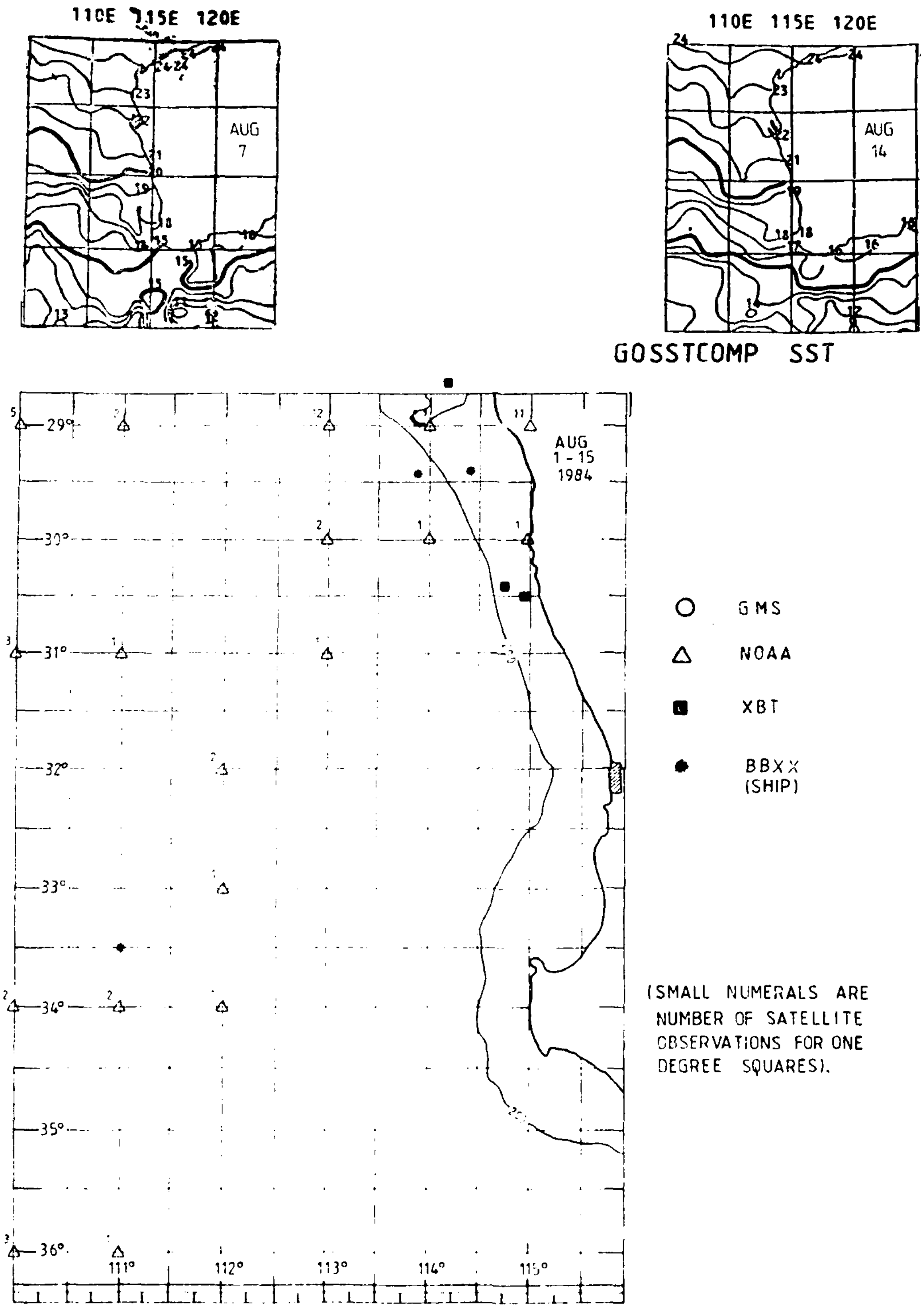

Fig. 2(a). SST Analysis for Aug.1-15 1984.

Period: August 1-15, 1984 (Fig. 2(a))

Data

XBT - 3 north along the coast

BBXX - 4

NOAA - sparse coverage

GMS - none

I.R. images - none (cloud covered)

NOAA satellite values appear too high, by 4 to 5°C in the north. BBXX are below the 20.8°C August maximum recorded in XBT below 30°S, and are within 0.2 - 0.4°C of the XBT. The BBXX at 33°30'S, 111°E is 1.8 to 3.6°C lower than near NOAA values. Contours cannot be drawn, in part occasioned by the small degree of variation in the NOAA SST values, which may or may not be a real feature.

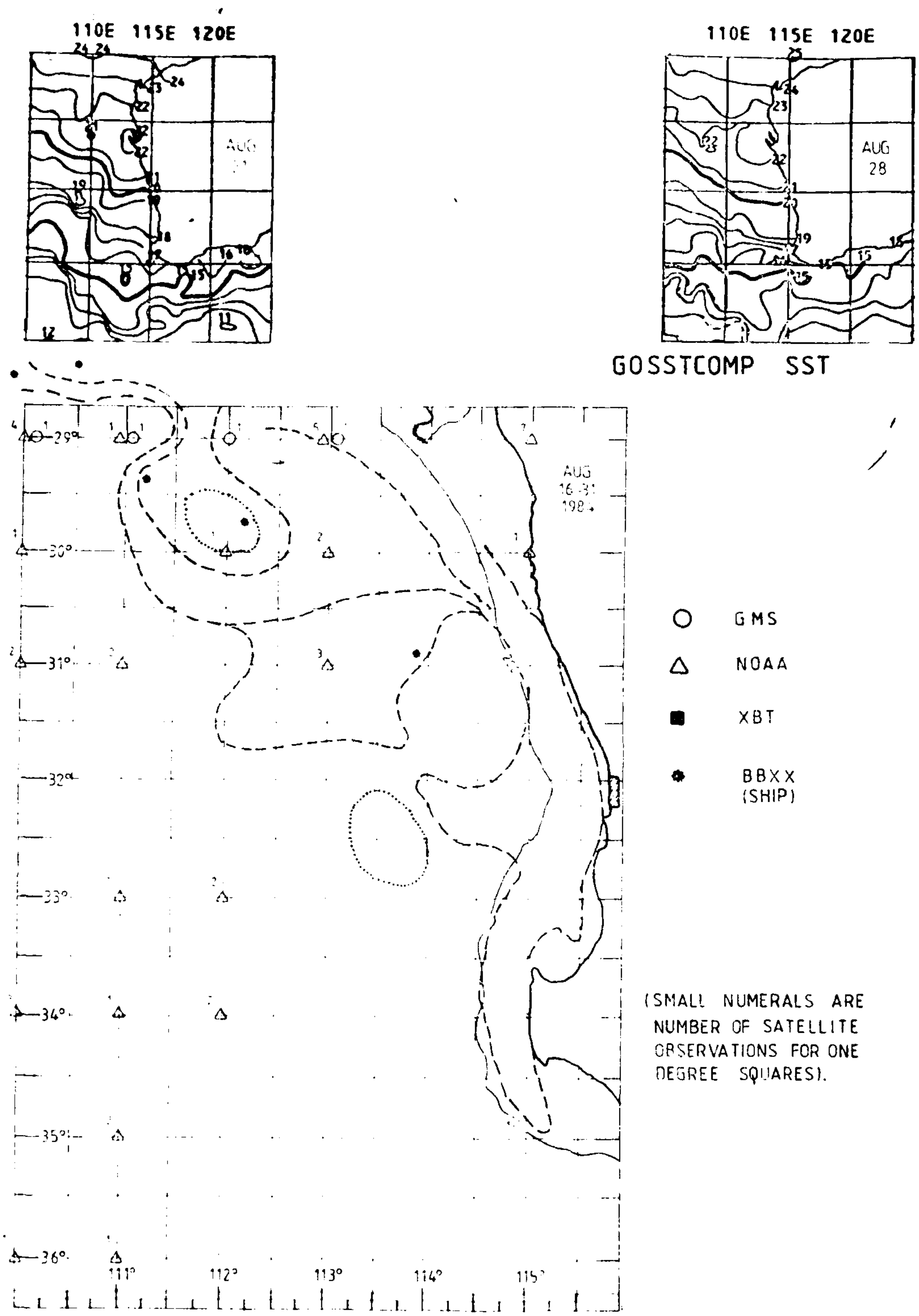

Fig. 2(b). SST Analysis for Aug. 16-31 1984.

Period: August 16-31, 1984 (Fig.2(b))

Data

XBT	-	none
BBXX	-	4 north of 31°S
NOAA	-	sparse coverage, better seawards and to the north
GMS	-	4 values along 29°S
I.R. images	-	Macquarie of 28th

NOAA values appear high, by 1.6 to about 3°C. GMS values appear very good with some low by up to 2°C. Only a few speculative contours can be drawn, based on BBXX, XBT, and GMS. A Macquarie image of 28 August does suggest a warm current along the coast to just south of Cape Leeuwin, and some frontal structure. Contours shown are drawn from the satellite imagery.

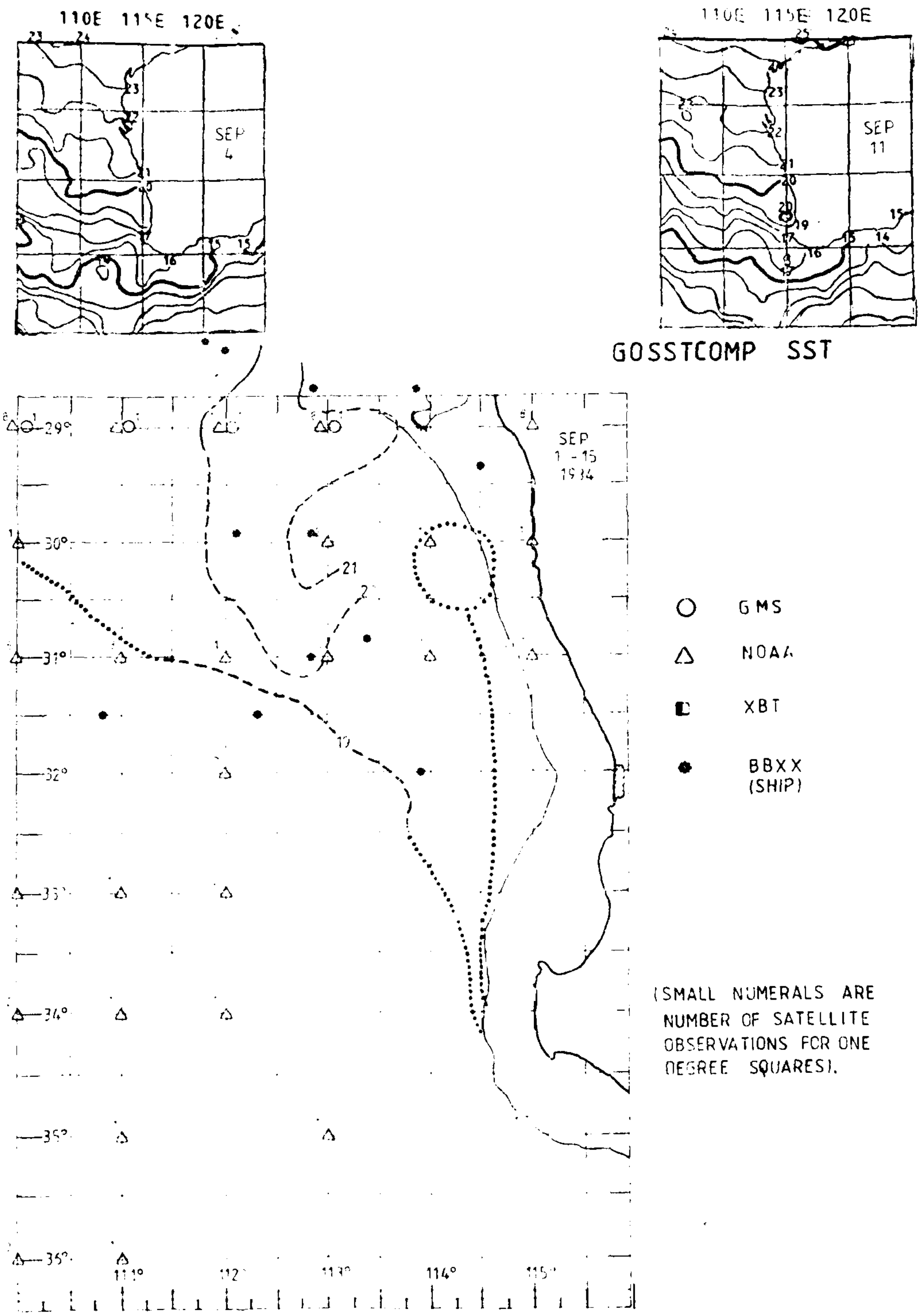

Fig. 3(a). SST Analysis for Sep. 1-15 1984.

<u>Period: September 1-15, 1984</u> (Fig. 3(a))

<u>Data</u>

XBT	-	none
BBXX	-	12 north of 32°S, (one 6°C too high?)
NOAA	-	sparse south of 31°S, good north of 31°S
GMS	-	4 values along 29°S
I.R. images	-	none suitable (cloud covered)

No subsurface measurements.

The GMS values appear reasonable. NOAA values are high by about 3°C. Some contours can be drawn in the north. A Macquarie image for the 12th does show faint indications of a coastal current from 30°S to Cape Naturaliste.

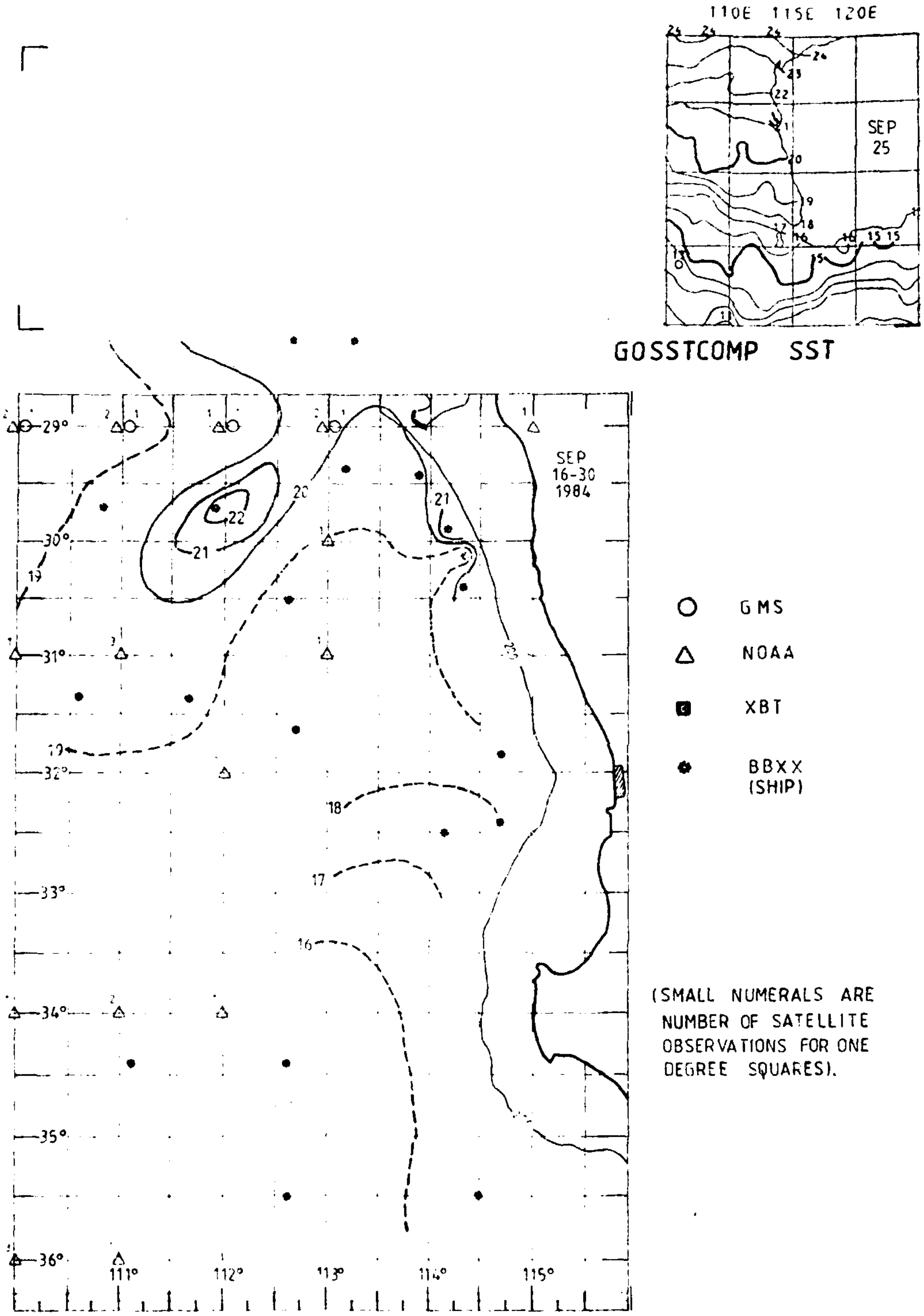

Fig. 3(b). SST Analysis for Sep. 16-30 1984.

Period: September 16-30, 1984 (Fig.3(b))

Data

XBT	-	none
BBXX	-	20, (1 north of 32°30'S)
NOAA	-	sparse
GMS	-	4 along 29°S (another 4 along 28°S)
I.R. images	-	none suitable

No subsurface measurements

There are BBXX (3 of) south of 33°30'S for the first time, and BBXX coverage to the north is very good. GMS values are within 1°C of nearby BBXX. NOAA values are high by about 3 to 4°C in the north, and 6 to 7°C in the south (34°S). Macquarie images for 20, 21st show very faint indications of a warm coastal current with warmer water off the Capes. Few contours can be drawn, however, because not enough GMS satellite values are available. NOAA SST values are not usable, differing by up to 7°C from southern BBX, and by lesser values in the north, i.e. there is not a consistent offset from ground truth values, but a north-south gradation.

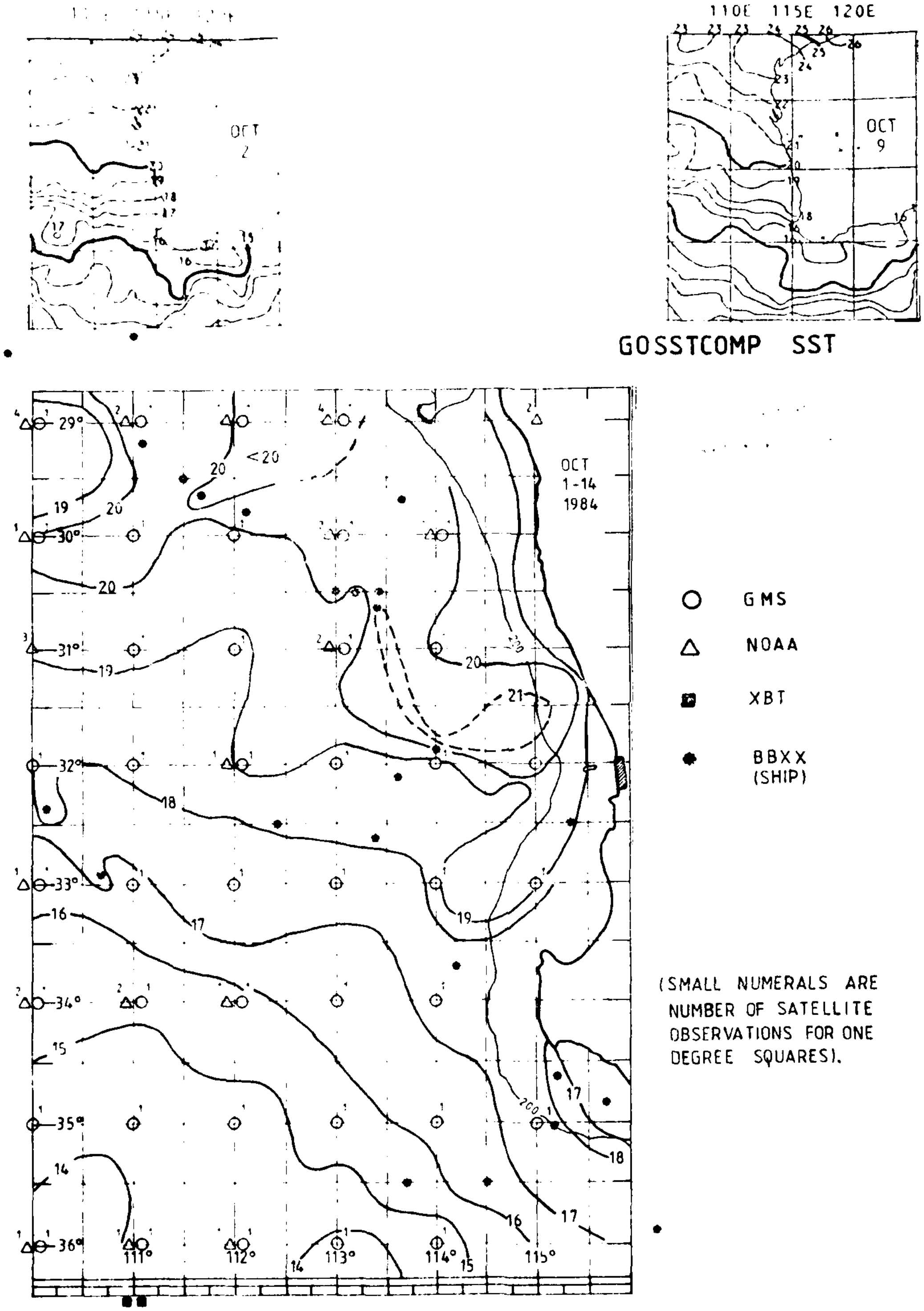

Fig. 4 (a). SST Analysis for Oct. 1-14 1984.

Period: October 1-14, 1984 (Fig.4(a))

Data

XBT	-	none
BBXX	-	24
NOAA	-	very sparse
GMS	-	63 values from the 10th, covering the whole area except north along the coast.
I.R. images	-	2 Macquarie images for 17th are used.

GMS values are usually within 1°C of BBXX, with deviations to over 3°C. At 36°S, 110°E, NOAA and GMS differ by 6.2°C on the 10th. At 34°S, 110°E the difference for the 10th is 7.6°C. Northwards the differences are 2 to 5°C and higher. GMS coverage is very good and is all dated the 10th. The Macquarie images show a body of warm water along the coast, and warm water south of Cape Leeuwin.

This period is the first for which contours can be drawn. The Macquarie image helps to give definition to the area off Perth. The analysis should serve as a starting point on which following periods can be based.

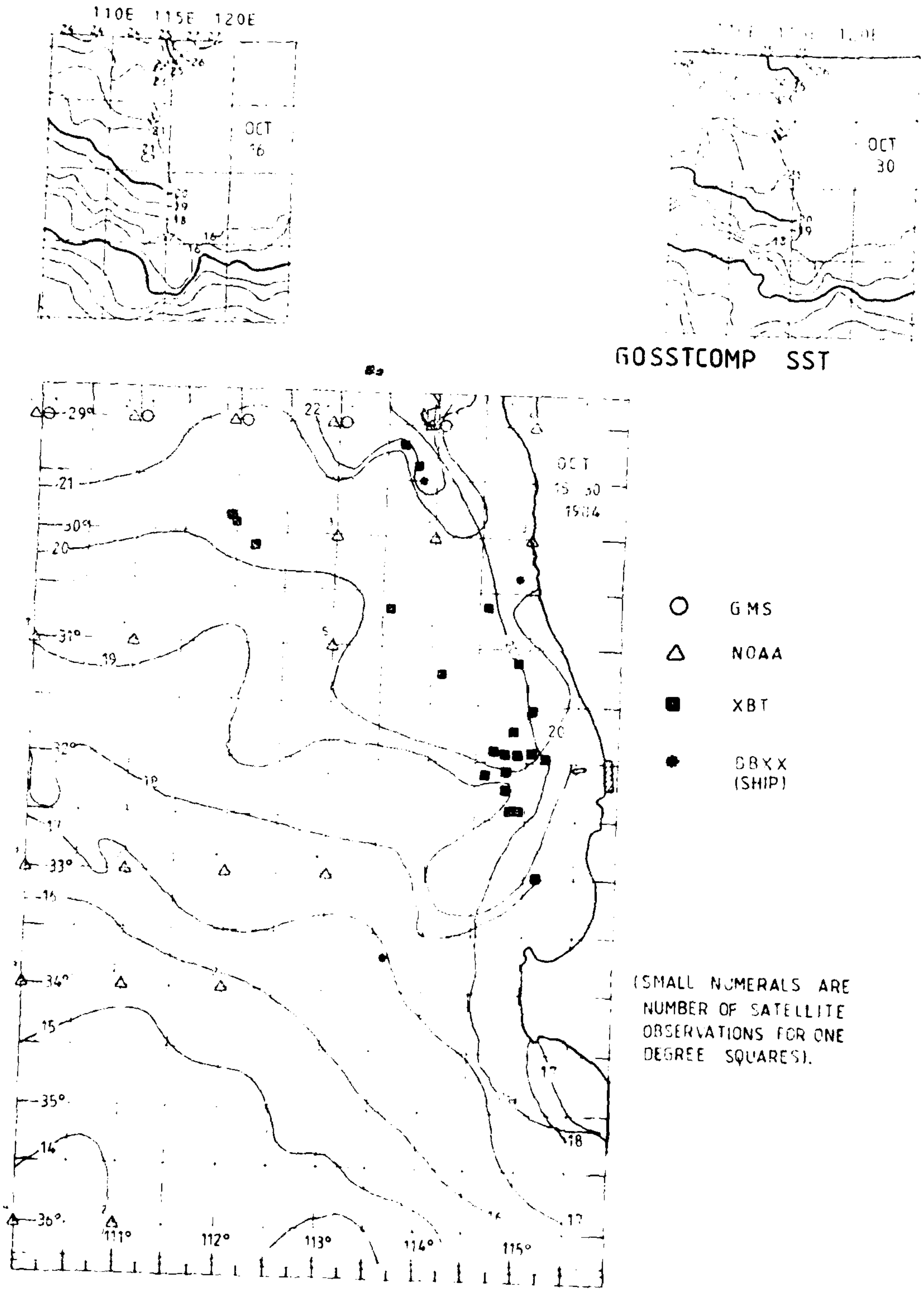

Fig. 4(b) SST Analysis for Oct. 15-30 1984.

Period: October 15-31, 1984 (Fig.4(b))

Data

XBT	-	16, (12 clustered west of Perth)
BBXX	-	5
NOAA	-	sparse
GMS	-	5 values along 29°S (and 4 along 28°S)
I.R. images	-	Macquarie of 24th shows warm water to the northeast along the coast to 30°30'S but nothing else.

The analysis from the previous period is carried over with 21 and 22°C contours added to the north near the coast.

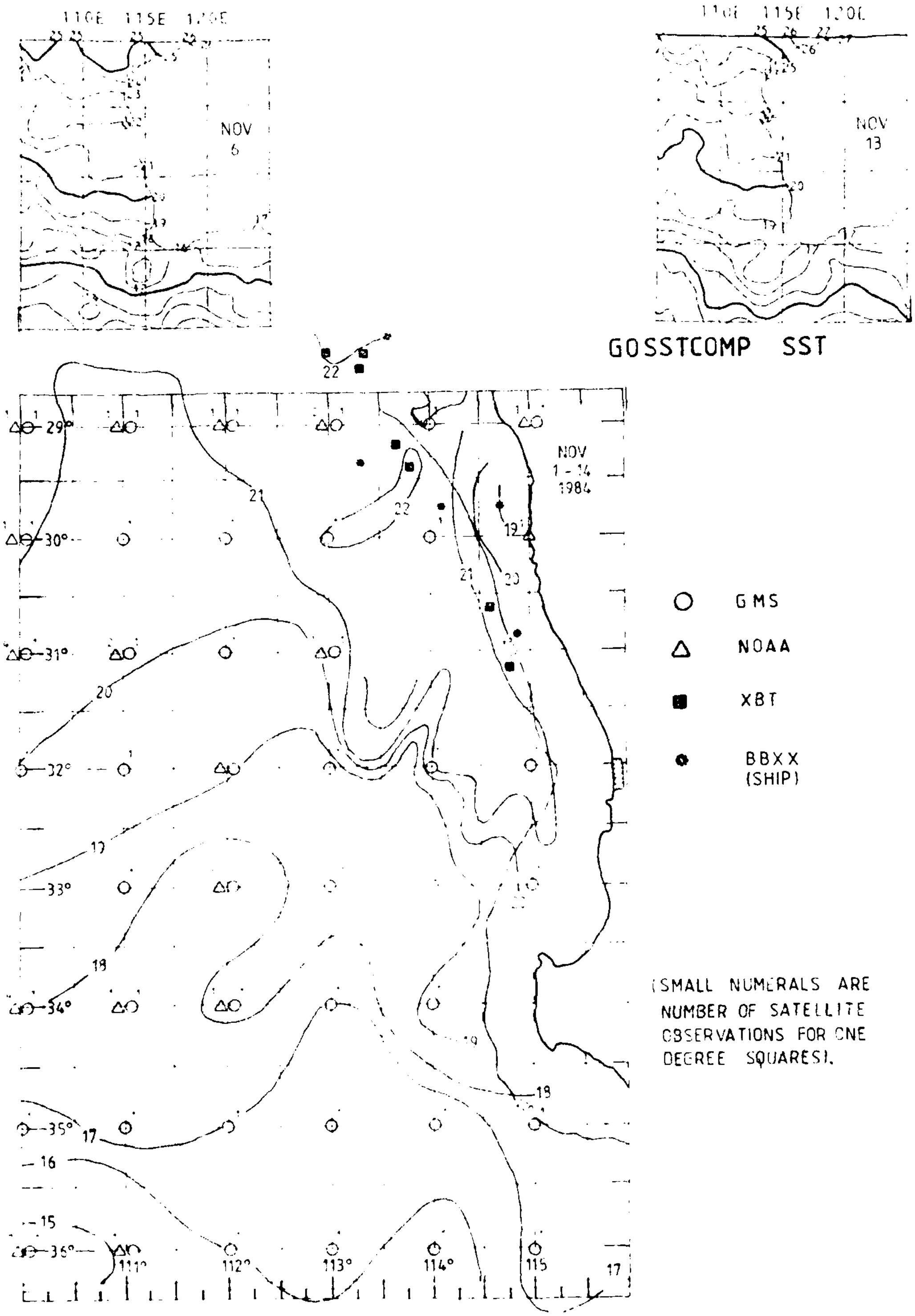

Fig. 5(a). SST Analysis for Nov.1-14 1984.

Period: November 1-14, 1984 (Fig.5(a))

Data

XBT	-	8 (4 north of 29°C)
BBXX	-	3 north of 31°S
NOAA	-	very few
GMS	-	good coverage of whole area (62 values from 3rd)
I.R. images	-	Macquarie of 6th shows some features to the north

Northern GMS values are usually within 1°C of BBXX. Contours can be drawn from the GMS data. These contours have been drawn independently of previous data periods. Waters are now warmer over the whole area from mid October by 1 to 2°C, and warmer water has moved southwards along the coast, so that previous data are incompatible with this period. General patterns of flow are roughly similar however. The analysis is similar to the classic flow pattern for the area deduced by Andrews (1977) for summer months. The Macquarie image shows a loop and ribbon in the north which gives added definition to the contours northwest of Perth.

The sharp change in SST for this period is shown in climatological averages given in Hamilton (1984). It appears care must be taken when extrapolating from previous analyses at this time of year (spring).

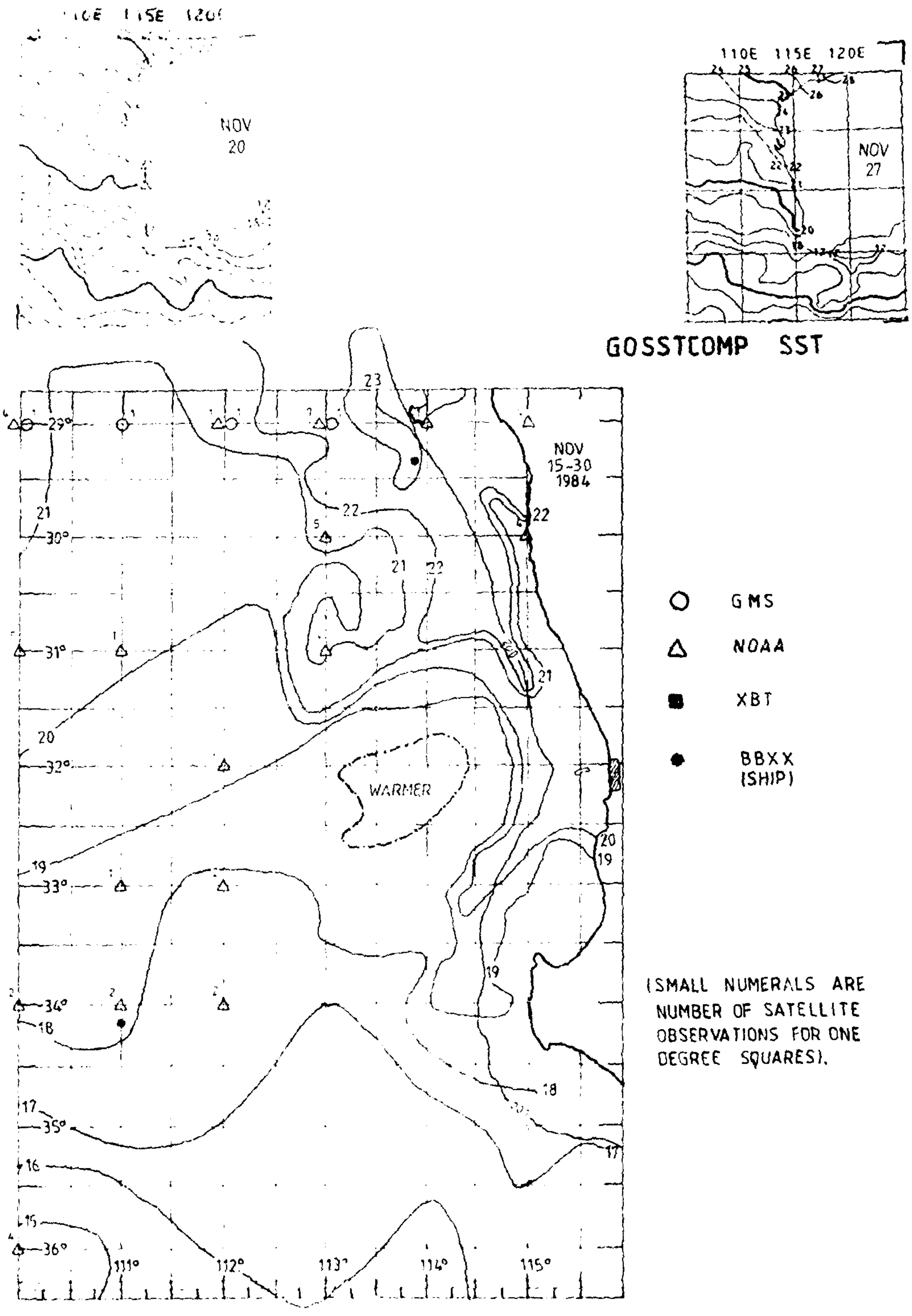

Fig. 5(b). SST Analysis for Nov. 15-30 1984.

Period: November 15-30, 1984 (Fig.5(b))

Data

XBT	-	none
BBXX	-	2 only
NOAA	-	sparse
GMS	-	4 values along 29°S (and 5 along 28°S)
I.R. images	-	WAIT of 27th, 28th. (27 shows north, 28 shows south).

The i.r. imagery clearly shows warm water moving southwards along the coast, extending almost to Cape Leeuwin, with a large loop off Perth, and a reverse spiral about 30°30'S, 113°E. (The "reverse spiral" refers to the fact that the feature here appears to be moving clockwise, in the reverse direction to that usually exhibited by warmer waters in the southern hemisphere.) Contours from the imagery indicate frontal positions, where isotherms are close together, but absolute SST values cannot be assigned as only one BBXX value is available below 29°30'S, and no GMS values below 29°S. NOAA values have previously been proven unreliable for absolute values. The northern GMS values for November 20th show temperatures to have increased by over 2°C since November 10th, so the previous data is incompatible with this period. There is little choice but to combine the analyses however, assuming the contours have not greatly changed in the 10 days. The satellite fronts are in broad agreement with trend of previous contours in the warm water along the coast, so this approach should work here.

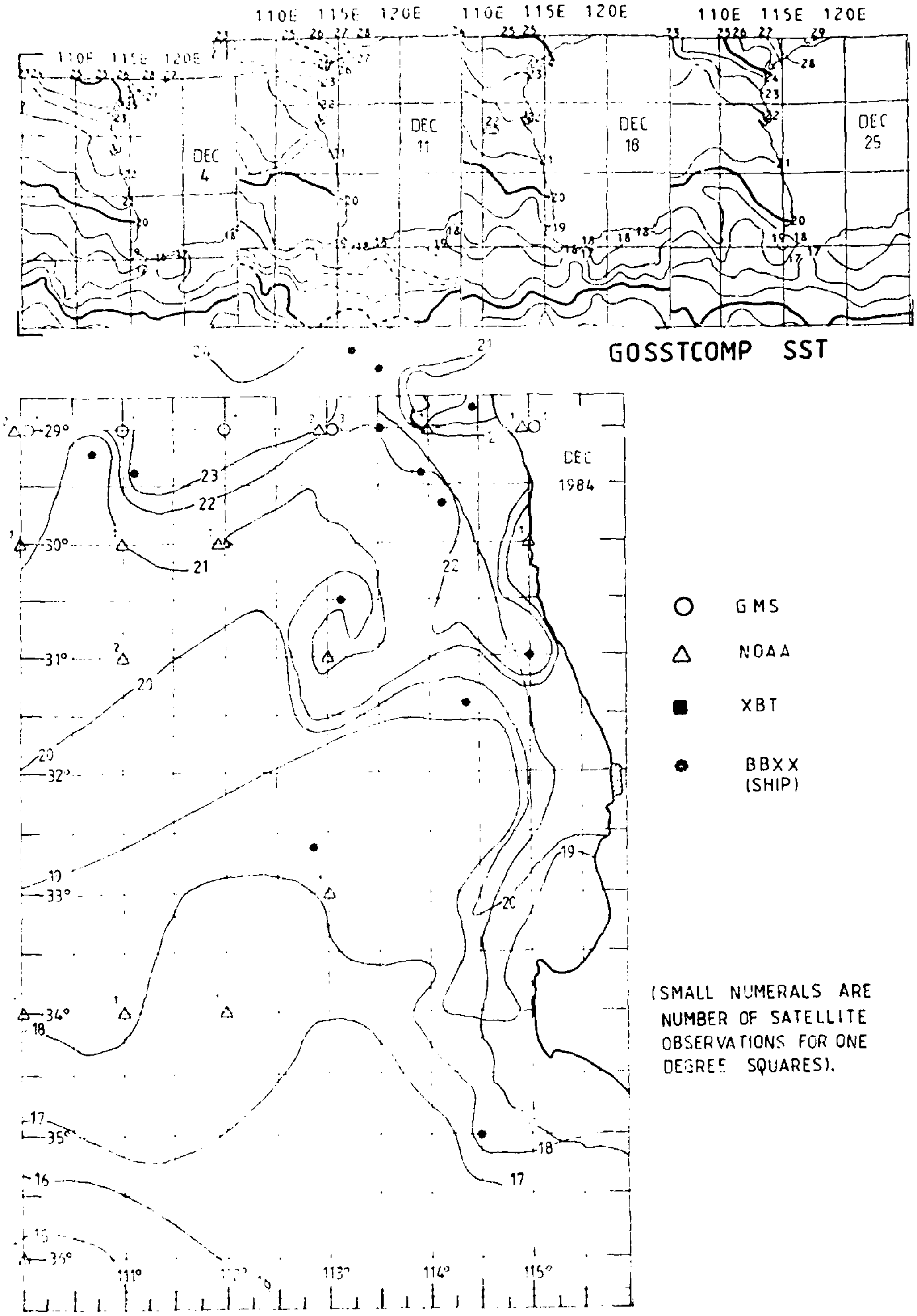

Fig. 6. SST Analysis for December 1984.

Period: December 1984 (Fig.6)

Data

XBT	-	none
BBXX	-	14 (11 north of 31°S)
NOAA	-	few values
GMS	-	4 values along 29°S
I.R. images	-	all WAIT images for December are over exposed.

The image for the 5th faintly shows features to the north, and suggestions of a front along the coast from 31 to 33°S. These features are in the same position as for the previous image of 27 November. The new BBXX values tend to support the previous period analysis.

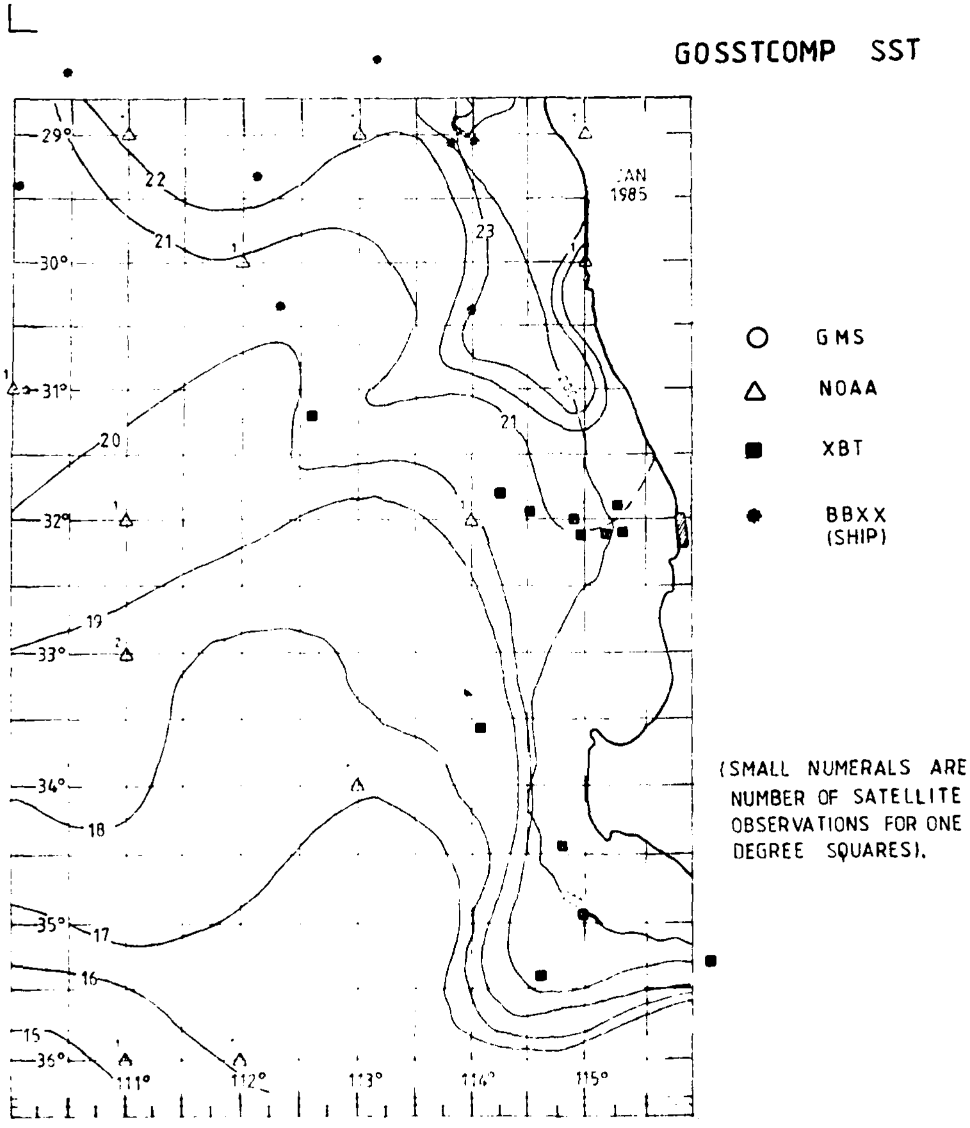

Fig. 7. SST Analysis for January 1985.

Period: January 1985 (Fig.7)

Data

XBT	-	12, mostly west of Perth
BBXX	-	8 (all north of 31°S)
NOAA	-	a few scattered values
GMS	-	none
I.R. images	-	none, all WAIT images overexposed.

The XBT show water over 20°C south of Cape Leeuwin, indicating warm waters still moving down the coast from the north, or heating of the whole area. The lone XBT off Cape Naturaliste suggests waters moving southwards. The NOAA summer values appear closer to ground truth values than in winter periods. The analysis is probably reasonable.

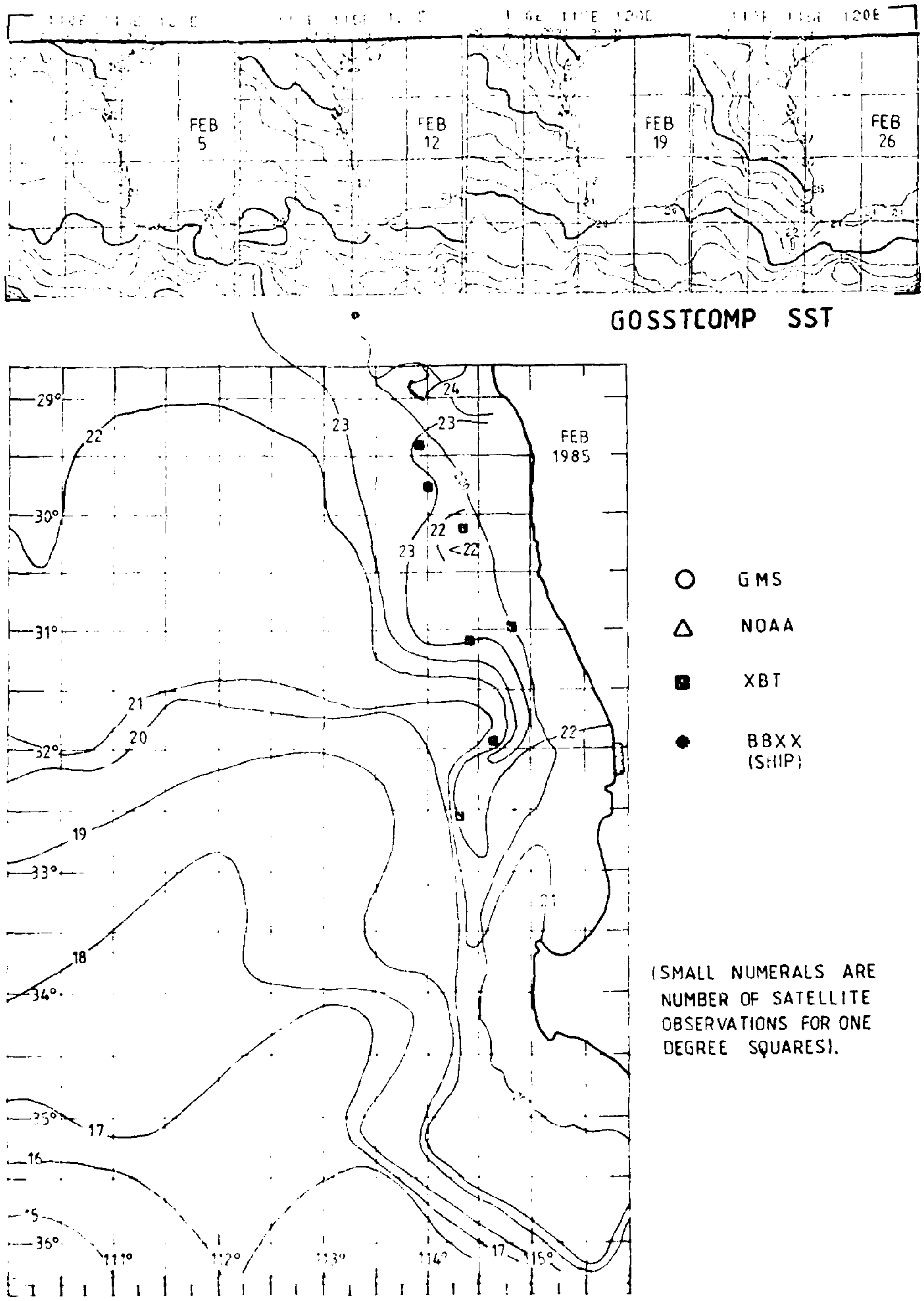

Fig. 8. SST Analysis for February 1985.

Period: February 1985 (Fig.8)

Data

XBT	-	8 (north of 32°35'S)
BBXX	-	none
NOAA	-	unavailable (undated telexes arrived mixed together)
GMS	-	unavailable (undated telexes arrived mixed together) except for 4 values along 28°S and one along 29°S
I.R. images	-	WAIT for 11th (indistinct coastal features), 13th (some fronts south of Cape Leeuwin), 20th (very faint), 22nd (usable north of 32°S).

The XBT show warmer waters off Perth, and to the north.

Speculative contours can be drawn.

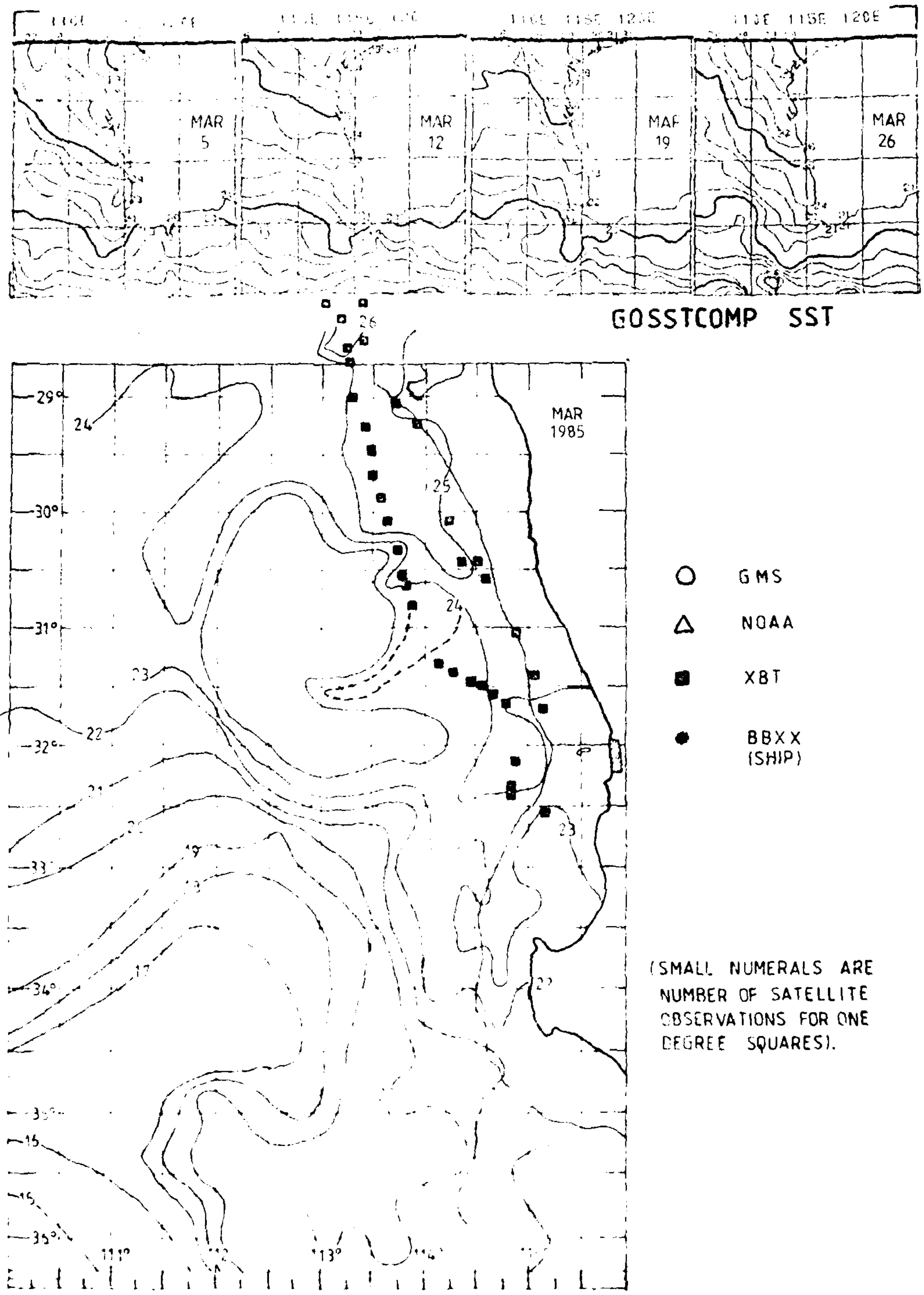

Fig. 9. SST Analysis for March 1985.

Period: March 1985 (Fig.9)

Data

XBT	-	37 off the coast north of 33°35'S
BBXX	-	none
NOAA	-	unavailable
GMS	-	unavailable
I.R. images	-	WAIT for 4th, 5th, showing features to north-east and south-east respectively; a gridded CSIRO image for 15th showing features to the south of 32°30'S.

Good patterns can be drawn, but the conversion to isotherms is speculative.

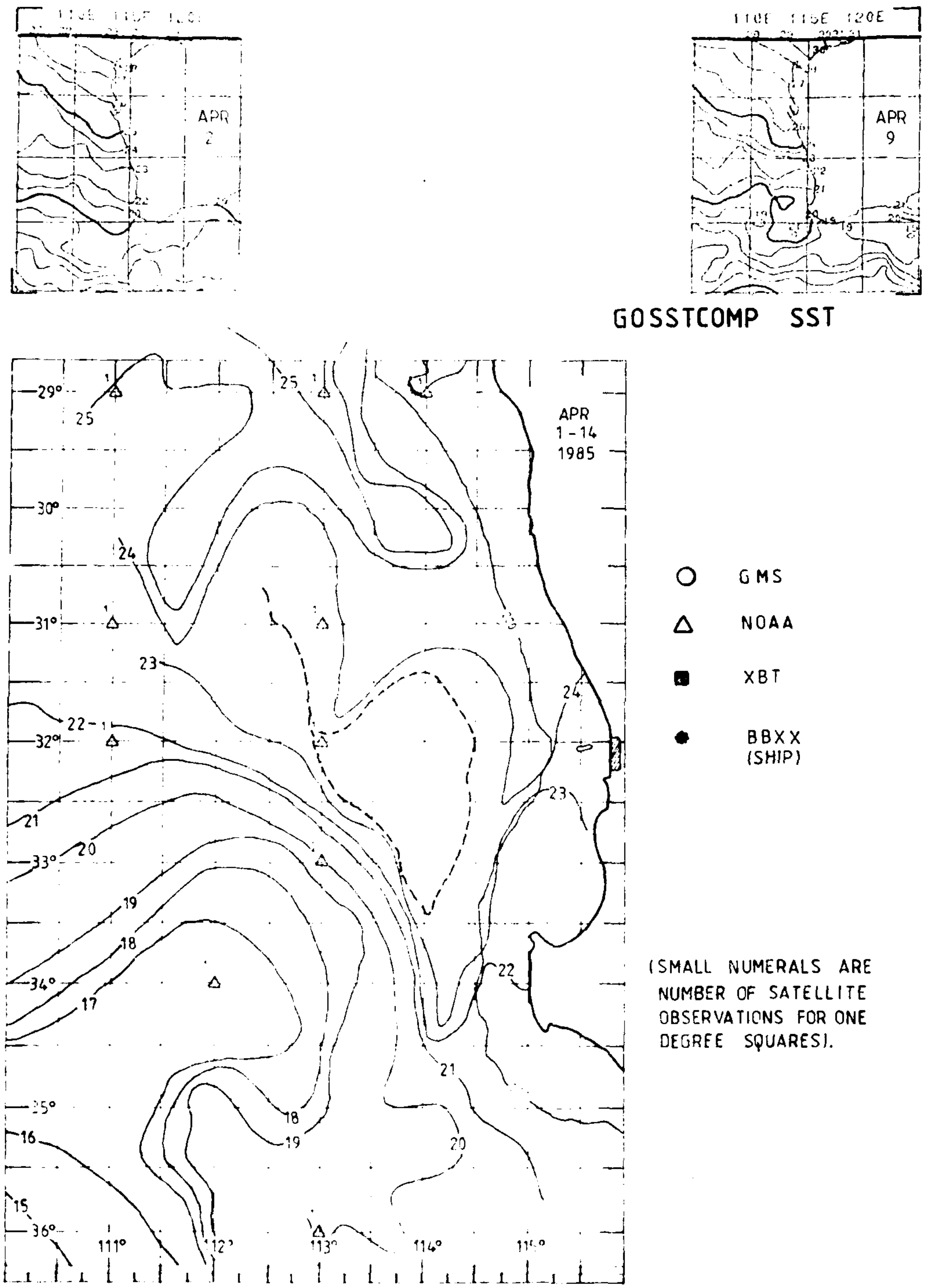

Fig. 10 (a). SST Analysis for Apr. 1-14 1985.

Period: April 1-14, 1985 (Fig.10(a))

Data

XBT	-	none
BBXX	-	none
NOAA	-	11 values
GMS	-	none
I.R. images	-	an image from March 28 is used.

The imagery (of March 28) is useful but contours and contour values are largely speculative.

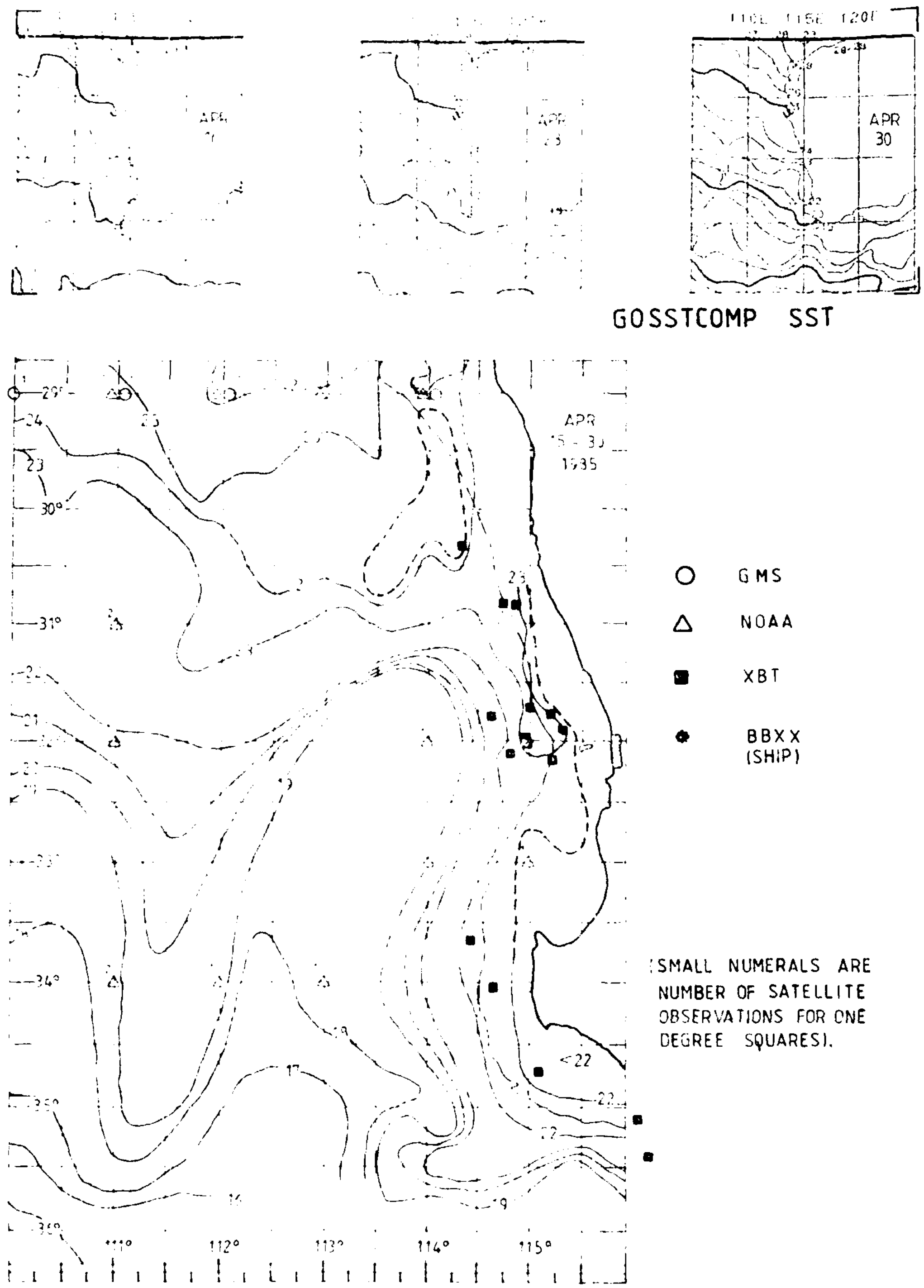

Fig. 10(b). SST Analysis for Apr. 15-30 1985.

Period: April 15-30, 1985 (Fig.10(b))

Data

XBT	-	17 (along the coast)
BBXX	-	none
NOAA	-	very sparse
GMS	-	5 values along 29°S (and 4 along 28°S)
I.R. images	-	WAIT of 19th (also for 1st May)

Some contours can be drawn. It appears that the warm pool centred about 32°15'S, 113°45'E for the previous period has spilled south along the coast, allowing colder waters from the south-west to advance further north-east. This is a speculative observation, but an interesting one, since such behaviour could lead to current jets.

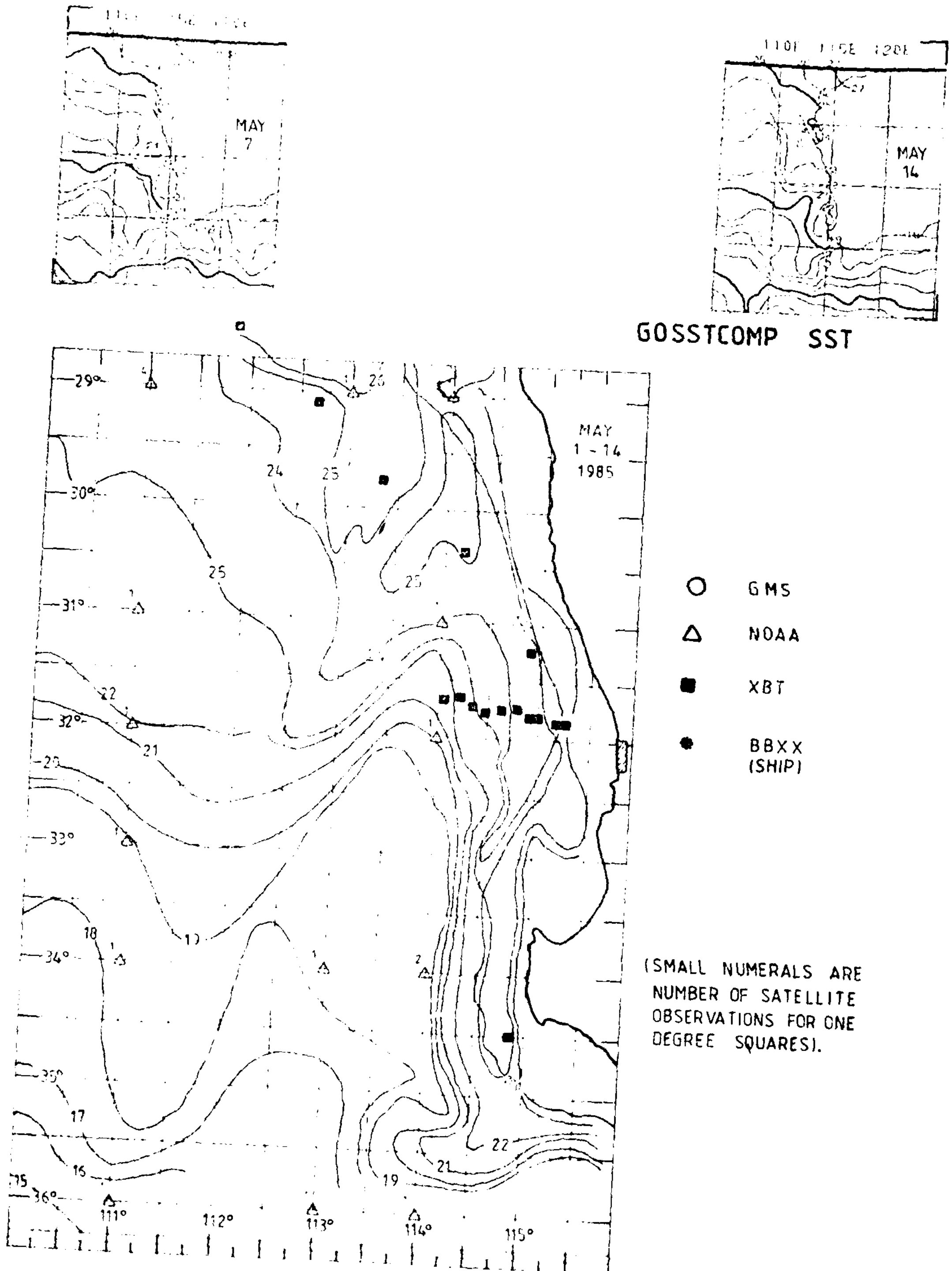

Fig. 11 (a). SST Analysis for May 1-14 1985.

Period: May 1-14, 1985 (Fig.11(a))

Data

XBT	-	16 (mostly off Perth)
BBXX	-	none
NOAA	-	very sparse
GMS	-	none
I.R. images	-	WAFI of 1st May, 10th May

The i.r. image shows a warm current stream off the coast and a front to sea. The image has been used for the previous period of April 15-30, and is used again here. The XBT off Perth are quite useful in assigning values to isotherms. A lone XBT south of Cape Leeuwin shows water at 23.6°C has now penetrated this far south.

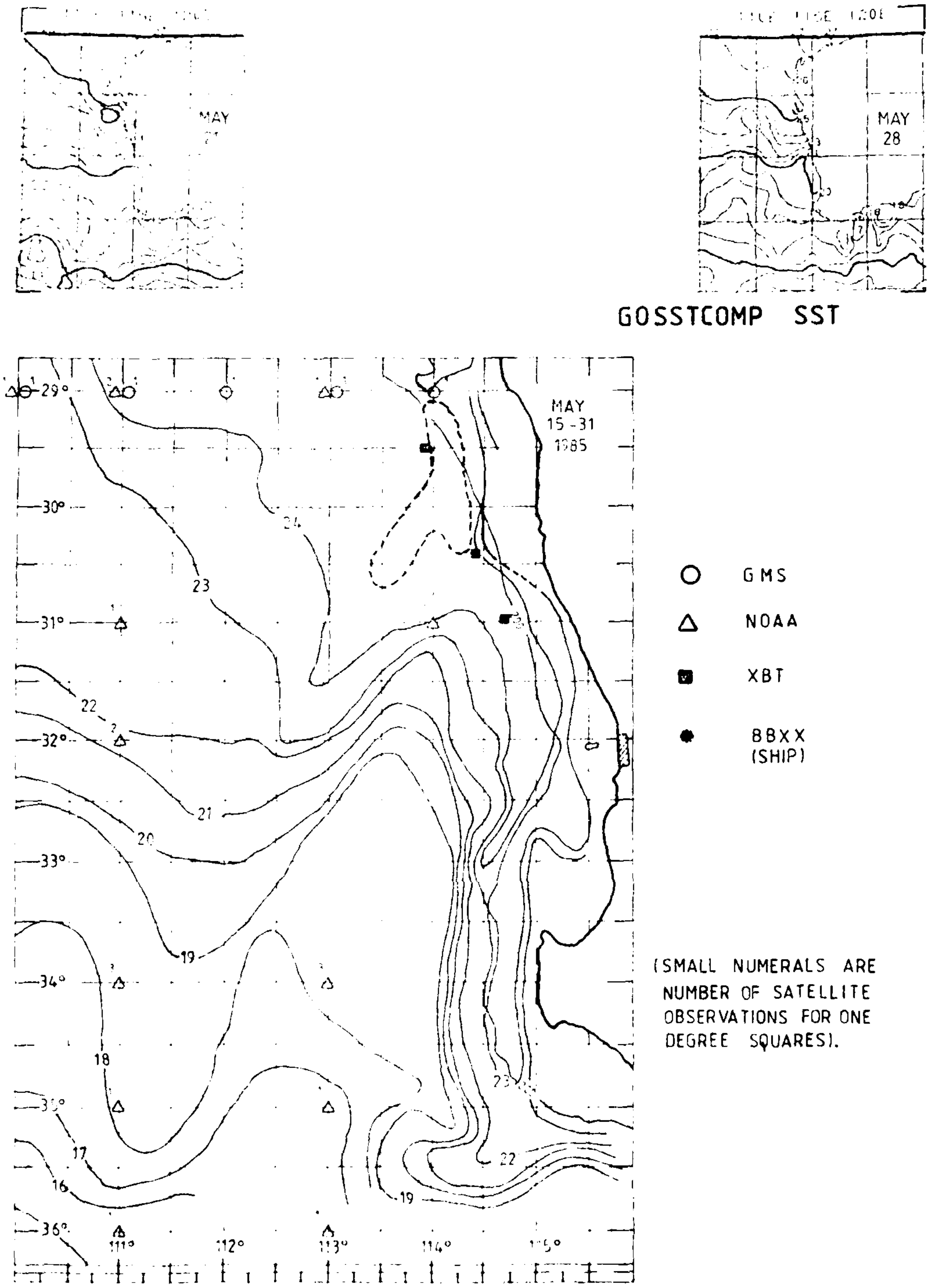

Fig. 11(b). SST Analysis for May 15-31 1985.

<u>Period: May 15-31, 1983</u> (Fig.11(b))

<u>Data</u>

XBT - 4

BBXX - none

NOAA - very few

GMS - 5 along 29°S

I.R. images - WAIT of May 19 suggests a current off the coast which is broader off Cape Leeuwin

The analysis from the previous period is carried over, with slight changes to the north. More data is needed.

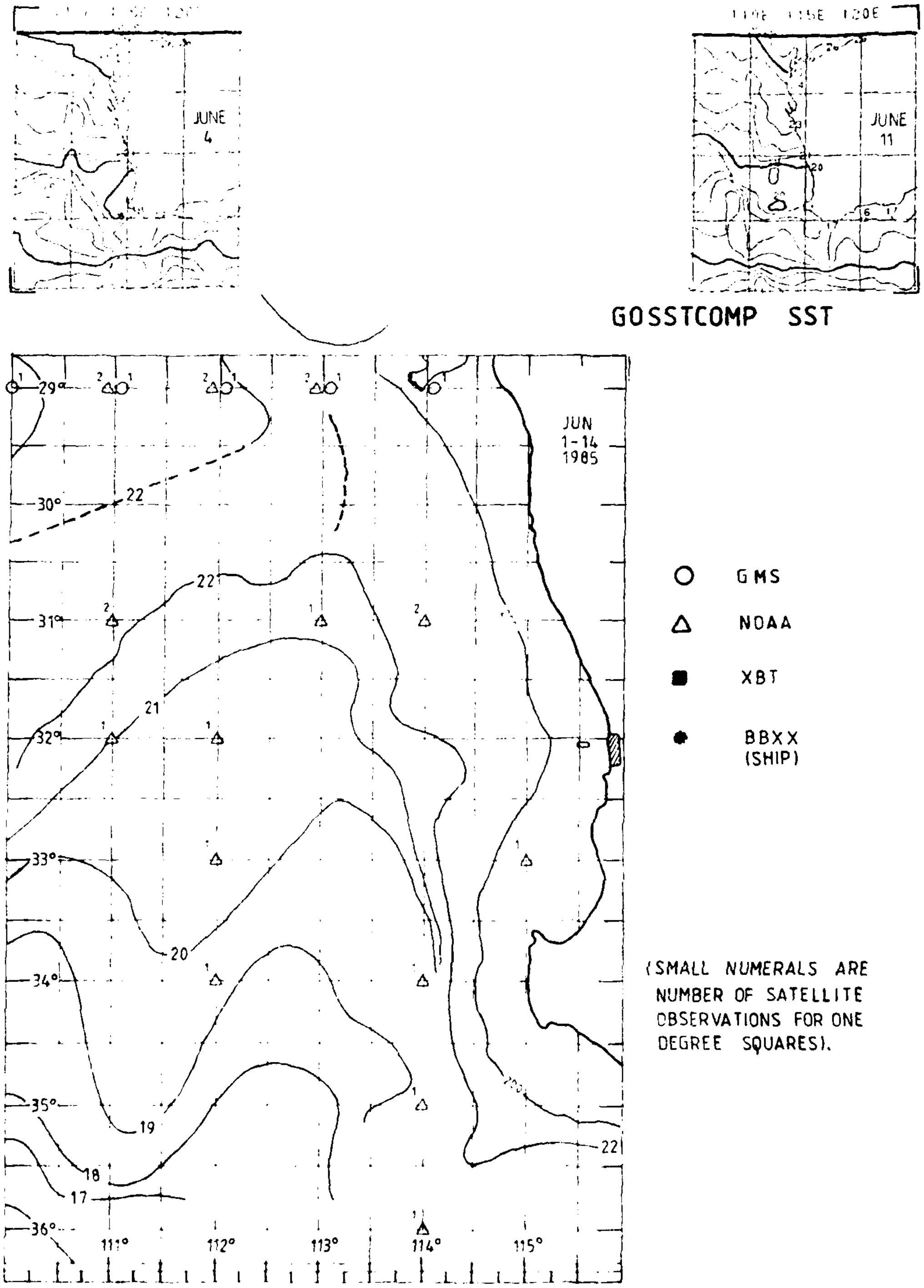

Fig. 12 (a). SST Analysis for June 1-14 1985.

Period: June 1-14, 1985 (Fig.12(a))

Data

XBT	-	none
BBXX	-	none
NOAA	-	very few values
GMS	-	5 values along 29°S(and 4 along 28°S)
I.R. images	-	WAIT of 13th suggests a front along 30°30'S, becoming parallel to the coast.

GMS values seem low, after values for the previous period, but could well be correct. The analysis for May 1-14 is carried over, with some change to the north-west. The analysis is in need of groundtruth values and a good satellite image as it is becoming highly speculative.

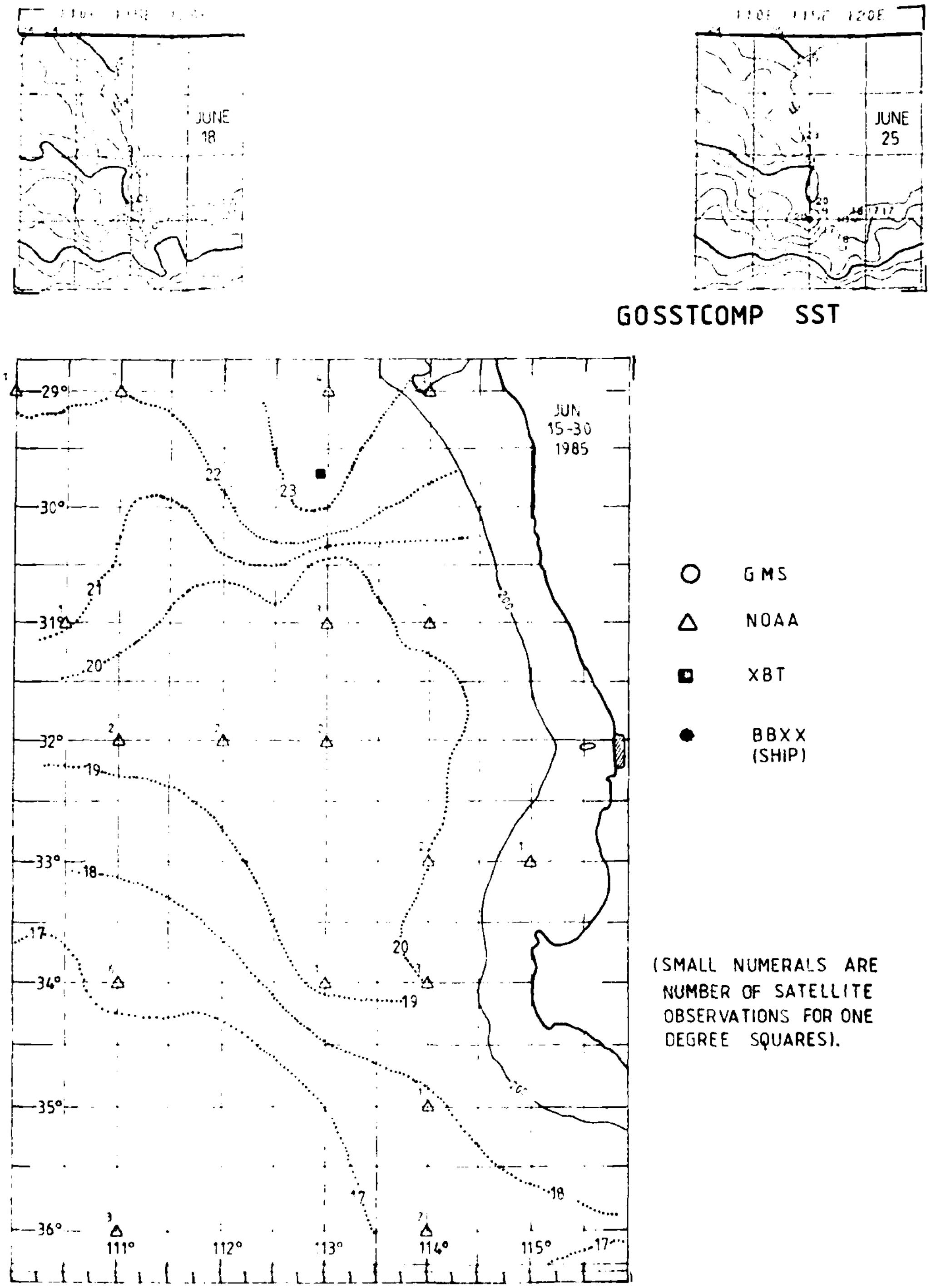

Fig. 12 (b). SST Analysis for June 15-30 1985.

Period: June 15-30, 1985 (Fig.12(b))

Data

XBT	-	one
BBXX	-	none
NOAA	-	sparse
GMS	-	none
I.R. images	-	none suitable

There is insufficient data for analysis. The last satellite image of June 13th does not show enough features to substantiate a full analysis. NOAA values look believable, and some indications of contours can be drawn from them.

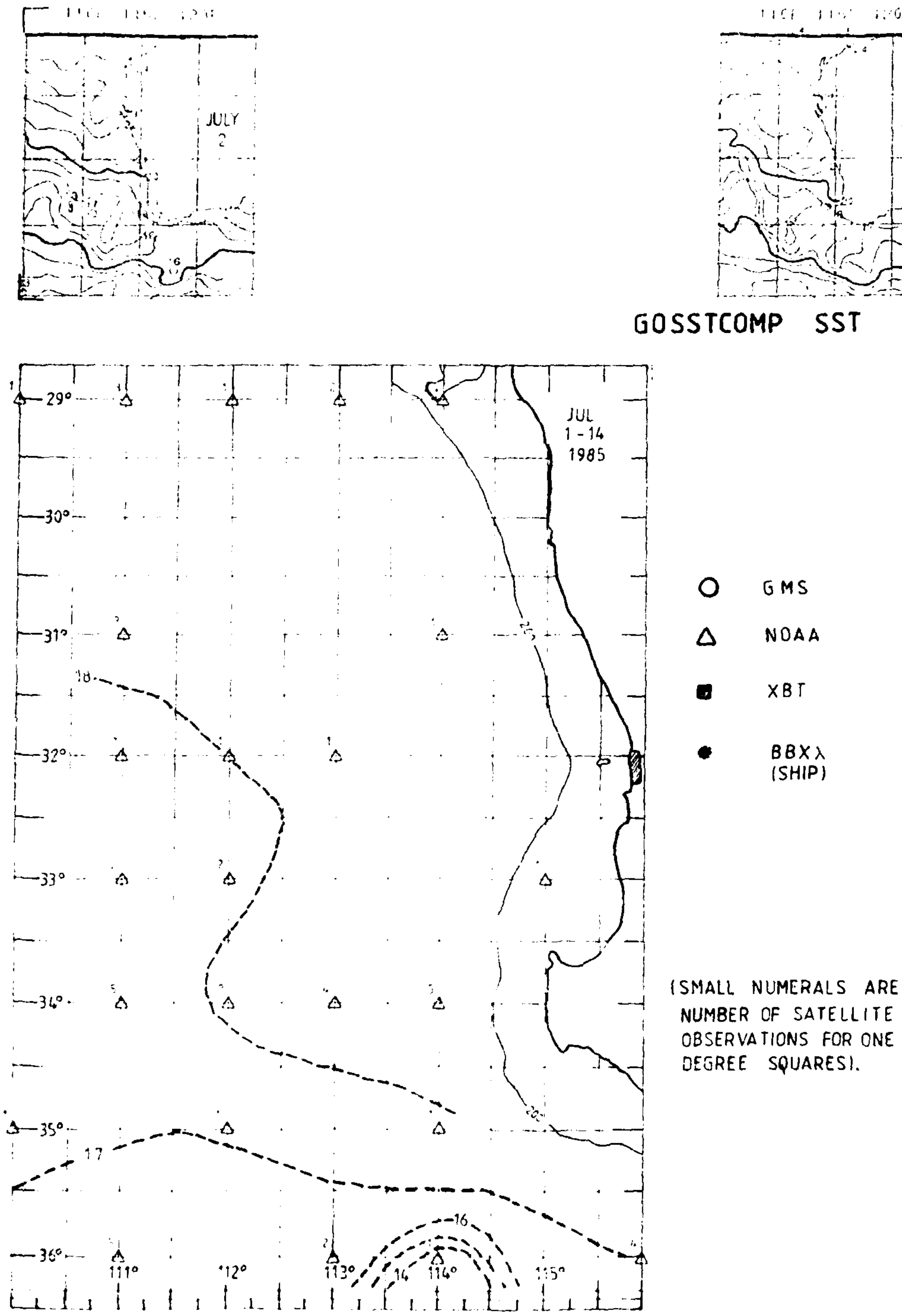

Fig. 13(a). SST Analysis for July 1-14 1985.

<u>Period: July 1-14, 1985</u> (Fig.13(a))

<u>Data</u>

XBT	-	none
BBXX	-	none
NOAA	-	reasonable coverage
GMS	-	none
I.R. images	-	none received.

No analysis can be made.

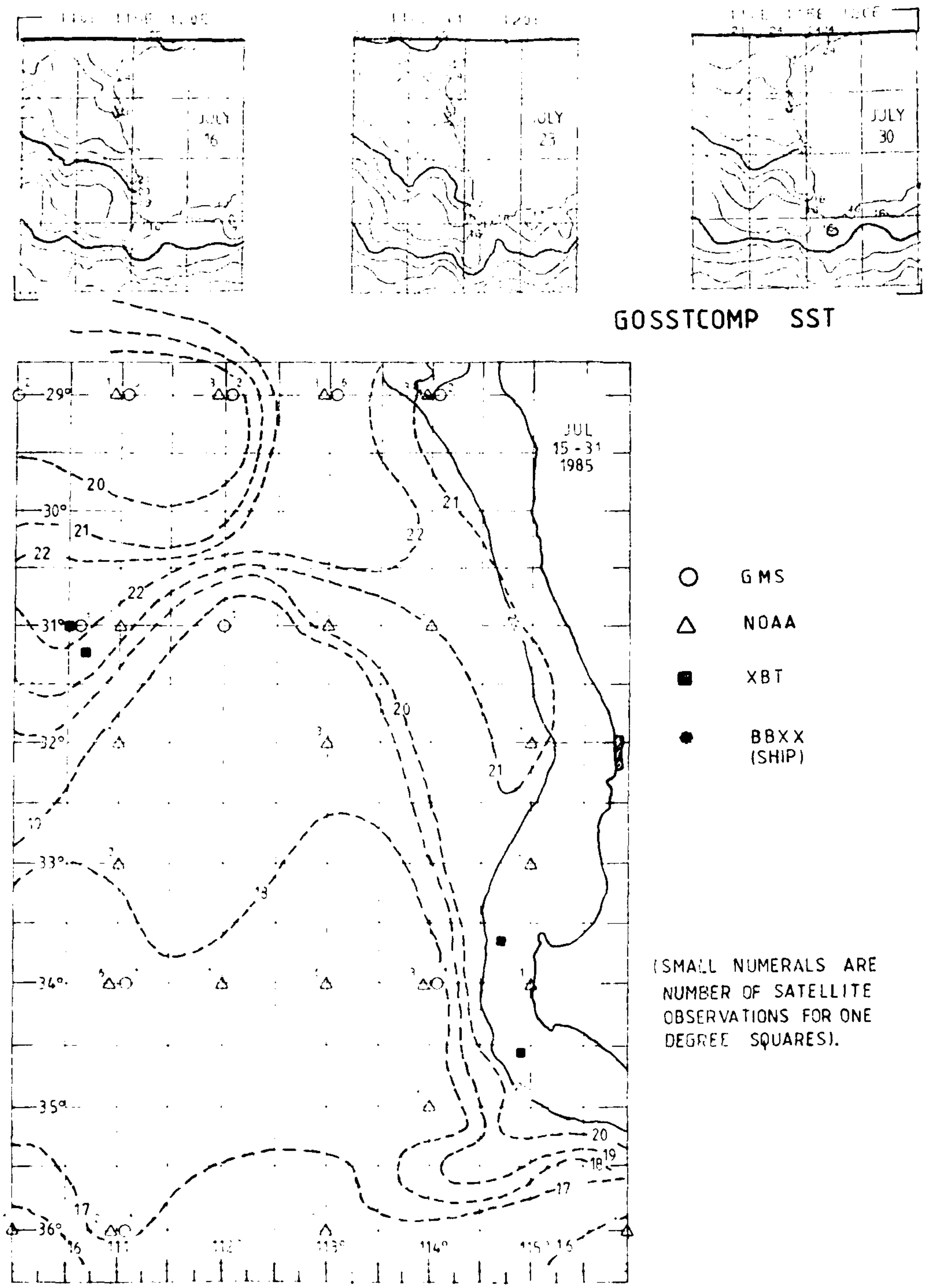

Fig. 13 (b). SST Analysis for July 15-31 1985.

Period: July 15-31, 1985 Fig.13(b))

Data

XBT	-	four
BBXX	-	none
NOAA	-	fair coverage
GMS	-	values along 29°S, few elsewhere
I.R. images	-	none received

A highly speculative analysis can be made. Lower temperatures are now seen throughout the area, having dropped sharply since May 1-14. Because NOAA values have improved in quality, more analysis can be made than for the same period last year, although the spread of values at a particular position is sometimes large (2 to 2.4°C).

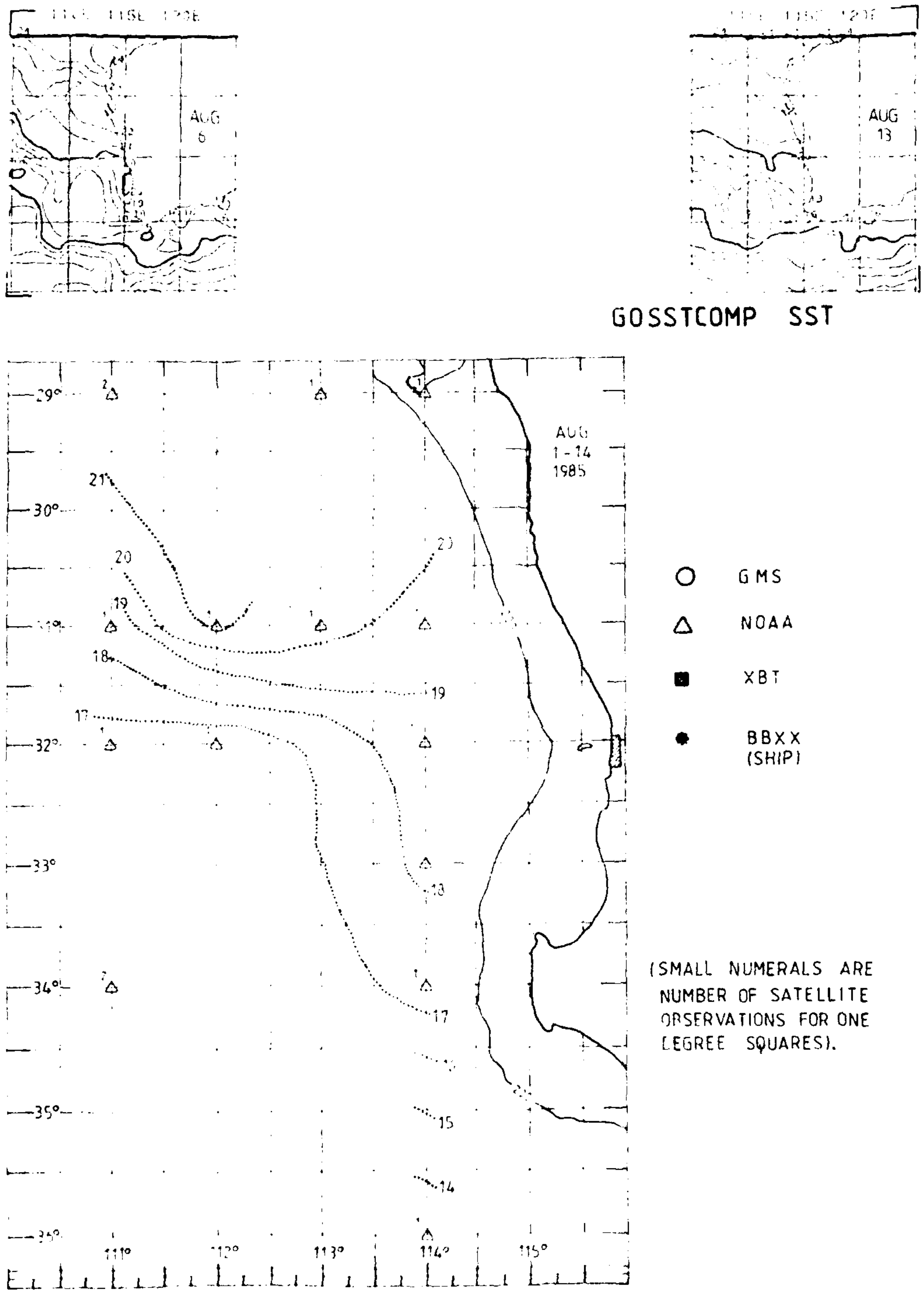

Fig. 14(a). SST Analysis for Aug. 1-14 1985.

Period: August 1-14, 1985 (Fig. 14(a))

Data

XBT	-	none
BBXX	-	none
NOAA	-	14 values
GMS	-	none
I.R. images	-	none received.

No worthwhile analysis can be made. Not all telex values seem to have been received, or perhaps cloud coverage prevented satellite values from being obtained.

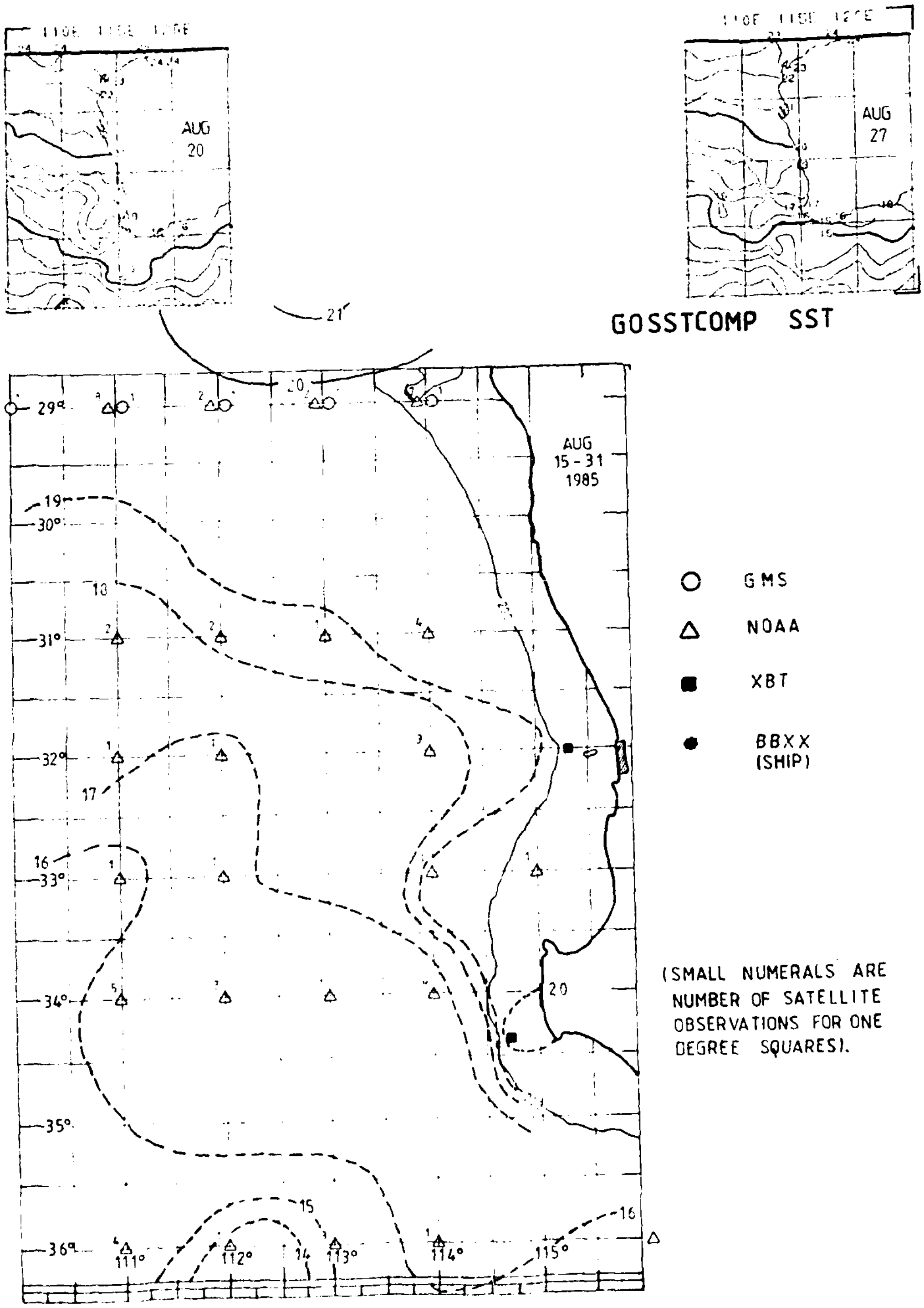

Fig. 14 (b). SST Analysis for Aug. 15-31 1985.

Period: August 15-31, 1985 (Fig.14(b))

Data

XBT - two

BBXX - none

NOAA - fair coverage

GMS - 5 values along 29°S (4 along 28°S)

I.R. images - none received

The NOAA values look much more realistic than for the corresponding period last year when values at 36°S were 20 to 22°C for 110-111°E instead of expected values of about 11-14°C. They are too spread for a good analysis however. NOAA and GMS are within 1°C of each other along 29°S. Some very tentative contours can be drawn (with some values from September 1) using NOAA values. The NOAA values are subject to variation of up to 2°C at the one latitude - longitude position.

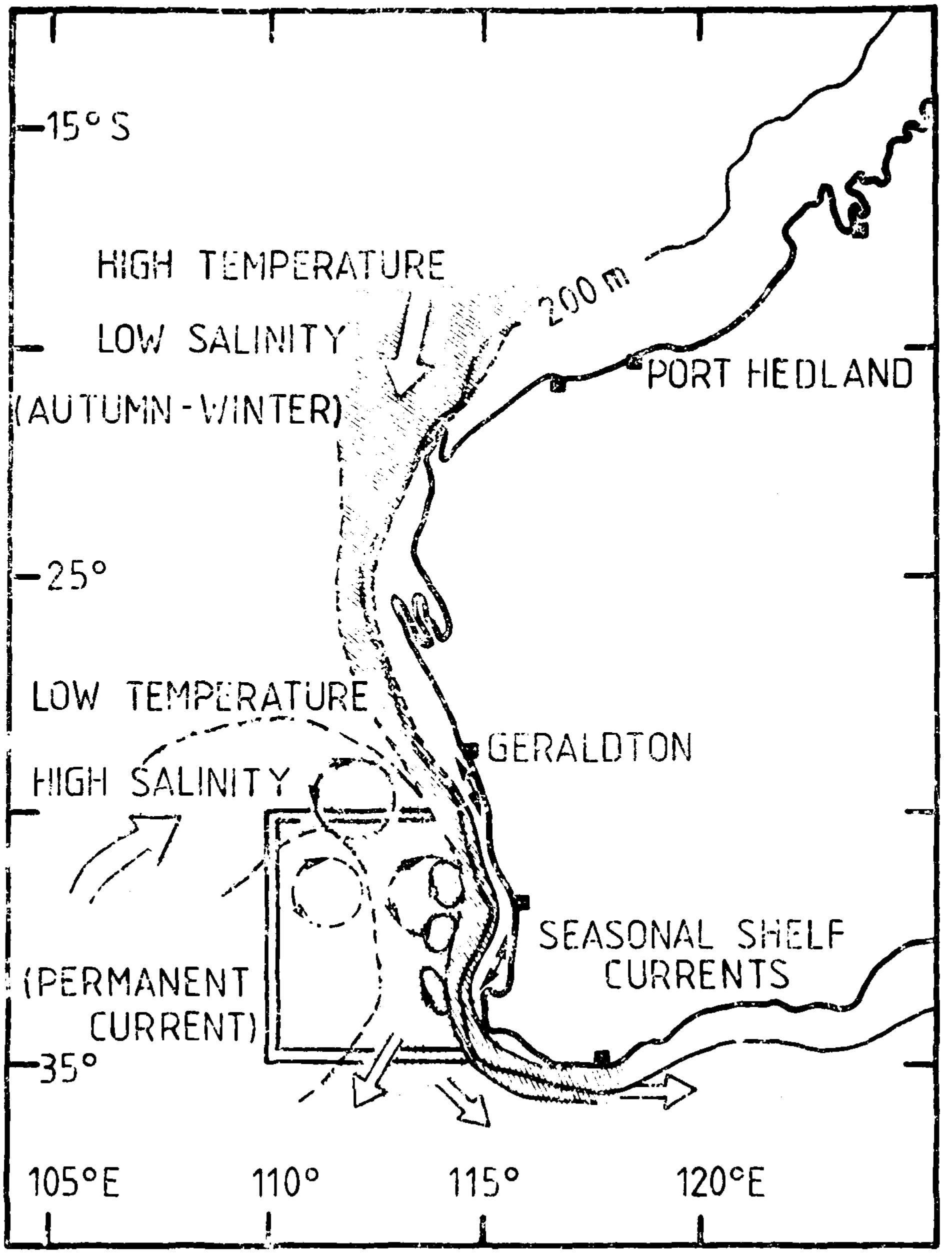

Fig.15 Schematic representation of typical circulation patterns in the South West Australian area. Circles denote eddies.

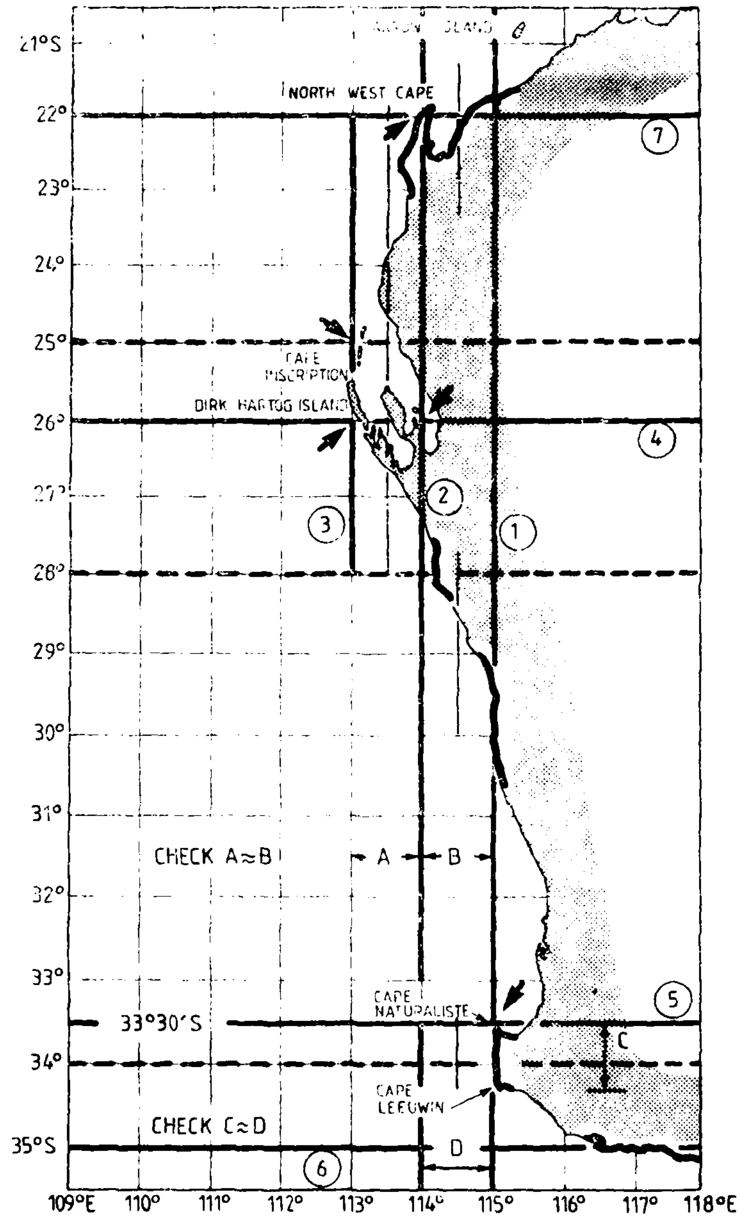

Fig. 16. Method of gridding the WAIT satellite images

Latitude and longitude lines were constructed in the order 1 to 7, using prominent coastal features as control points.

6. VALIDATION OF THE ANALYSES

A proper validation is not possible since independent analyses for the period are not known to exist. Allan Pearce from CSIRO in Perth may have some SST contours derived from the satellite data received there, but this has not been ascertained. The analyses can be compared roughly with weekly GOSSTCOMP analyses since the NOAA values from which these are derived were not used here for much of the analysis period. The GOSSTCOMP analyses show broad trends only, and do not usually show fronts or oceanographic features (Hamilton, 1983). The GOSSTCOMP analyses shown appear consistent with the broad patterns and absolute values expected for the area. Why the telexed NOAA values were so far in error is not known, since the GOSSTCOMP charts are eventually derived from such values. The telexed NOAA values appear to belong to areas farther north.

7. DISCUSSION AND CONCLUSIONS

It was found that a fortnightly period was the shortest time span over which analyses could consistently be attempted. This was the period needed for numbers of satellite values to reach usable levels. Table I on page 36 shows the number of data values for each period. Except for March 1985 few useful XBT were available, so that subsurface analyses could not be made. For this reason, only SST contours were drawn. Indications are that SST fields can show subsurface structure and flow patterns (Andrews, 1977; Hamilton, 1985) to some extent. Andrews (1977) discusses relations between SST and MLD patterns for four summer cruises. Hamilton (1985) gives some seasonal and statistical results for MLD, and relations between MLD and SST values.

Ship Temperature Observations

Merchant or other ship SST observations were not received for the area after January 1985, but perhaps they were simply not passed on to RANRL. This represented a serious loss of ground truth data, the few scattered values available often being the only means of assigning absolute values of SST to contours. The ship observations and XBT are also necessary to check the absolute satellite values. XBT were usually limited to coastal areas north and west of Perth, with less than 5 XBT in the area on the average for about twenty of the twenty-eight fortnightly periods considered. BBXX SST values usually appeared good, but some values were too high by 6°C, when compared to monthly maxima for the period 1955 to 1980 given in Hamilton (1984).

Satellite Absolute Values

At the start of the analysis period NOAA values were too high by up to 7°C and showed little variation over the area so contours could not

be drawn from them. They were closer to groundtruth values in summer than in winter. From May 1985 they looked more realistic and may now be able to be used. For this reason the NOAA values were not able to be used in the analyses until July 1985, when comparison with GMS values showed differences of about 1°C (to less than 1.5°C). The poor quality of NOAA data was unexpected since an evaluation of GOSSTCOMP SST contour charts for the eastern Australian ocean area for September 1982 to May 1983 had shown the charts to be very good with absolute values superior to those of GMS (Hamilton, 1983). GOSSTCOMP charts are derived from the NOAA values. Moreover the contour values on the GOSSTCOMP charts for the West Australian area for the analysis period were within expected limits, being 4 to 6°C lower than the telex values. The NOAA values are essential to analysis because they were usually regularly available over the period considered, but GMS were not. Of the 48 1° x 1° points in the area 29-36°S, 110-115°E, the average number covered per fortnight by NOAA was 15. The average number of points covered by GMS was less than 3. However it has since been discovered that not all data may have been received because of an error in the original request to NWC Nowra.

GMS values were often limited to 28 and 29°S. On October 10th and November 3rd 1984, however, coverage was obtained over the whole area, enabling two good complete analyses to be made. Forty two of the 48 1° x 1° points in the area 29-36°S, 110-115°E were covered for each analysis. The highest number covered by NOAA in any period was 26. The absolute GMS SST values appeared to be very good over the whole analysis period, this again being a most unexpected result, differing from earlier results for the east coast (Hamilton, 1983). New algorithms have been used for GMS values since November 1983, apparently to good effect. The area analysed should be extended north to 28°S to take advantage of the GMS values often available on this latitude. Frontal regions tended to occur in this area. The values outside the boundaries of the area should also be used to help define the edges of the area.

Satellite Imagery

WAIT satellite imagery was not available until November 16th, 1984. Reception of satellite imagery is suspended by WAIT from July to October because of heavy cloud coverage over the area. The extreme cloud coverage is seen in GMS images received by Macquarie University every one or two days. GMS images for August 28, October 17, 24 and November 6 showed some indications of features. GMS images were not received by RANRL after November 1984. In July and September only one image for each month very faintly suggested a warm coastal current. The WAIT images for December, January, and adjacent periods were rendered useless by apparent over-exposure. Good images should otherwise have been obtained. Only one temperature colour scale is used and the images usually show features more clearly to the north than in the area considered.

Perhaps because of the December-January over-exposures, only 16 WAIT images showed features useful for analysis. Almost half of these were very faint suggestions only. At least 13 images were received on average for each month. To be more useful the images need to be gridded and to be enhanced in the area of interest. Such features should be available in future.

It is not certain that all data for the analysis period was received. It is known that not all XBT data were received in signal format, and the absence of ship observations from April 1985 on is odd. A more formal means of data collection is needed than that used here, where telexes used by the Naval Weather Centre were passed on to RANRL. Naval ships must signal all XBT data. XBT should be dropped for depths of 50 m and over, and not the usual 200 m limit, to define the Leeuwin current boundaries.

For February and March 1985 the telex values for NOAA and GMS could not be used, as all telexes arrived at RANRL together and the telexes are undated for month (and year). Only a few GMS values were available in this period however. The telexes should be manually dated as soon as they are received to avoid such loss of data.

To summarize, the analyses were made with only a few scattered XBT and ship observations, a relatively few satellite images, and a low number of GMS values. Only the period October 1-14 and November 1-14 1984 could be satisfactorily analysed. Analyses were kept valid in some other periods by the few values available coupled with satellite images, and appeared reasonable based on knowledge of general conditions in the area. Satellite imagery was lost for December to January, and telex information lost from February to March 1985. One good satellite image per month appears sufficient to keep analyses valid when absolute SST data values are low in number.

In view of the small usable amount of data, it is surprising that any product at all was obtained. Better satellite imagery should in future be obtained in summer, and images could perhaps be more favourably enhanced in other months for the area. If the NOAA values continue to be usable from now on a good product should be able to be maintained.

CONCLUSIONS

The results are very encouraging for real time analyses in summer months, but not for winter, unless the NOAA values continue to to be valid. For winter analyses, cruises or AXBT flights must be scheduled or a system set up to obtain SST observations from any tuna fisherman in the area.

Co-operation with WAIT is essential for this last item. WAIT have indicated that they would be willing to participate in a real-time analysis scheme. The satellite imagery processed by WAIT is necessary for the success of such a scheme.

CSIRO are also working on satellite products for the area (Pearce, 1985). Buoy data would also be very useful. See Hamilton (1984) for further details of data sources. WAIT are themselves investigating means of producing SST contour maps. It might be possible for both NWC Nowra and WAIT to initially produce independent analyses. This would be a good means of validation.

At present the data precludes subsurface analyses. Some indications of subsurface structure can be inferred from SST data using the climatological relations given in Hamilton (1984), and further seasonal relations are also available from the author. A useful real time analysis scheme for the area therefore appears to be possible with the present data sources.

JN0493
D23007

TABLE I Number of data values in fortnightly periods

	JULY 1984		AUG		SEP		OCT		NOV		DEC	JAN 1985	FEB		MAR		APR		MAY		JUN		JUL		AUG	
XBT	0	0	3	0	0	0	10*	16	8	0	0	12	8*		37*	"	0	17	16	4	0	1	0	4	0	2
BBXX	6	3	4	4	12	20	24	5	3	2	14	8	X		X	X	0	0	0	0	0	0	0	0	0	0
NOAA values	18	11	18	19	26	15	17	21	15	17	15	12	X		X	X	10	12	14	12	14	18	23	20	13	21
GMS values	1	2	0	4	4	4	41	5	42	4	4	0	X		X	X	0	5	0	5	5	0	0	9	0	58
WAIT image	-	-	-	-	-	-	-	-	-	2	((1))	-	(2)	(2)	3	1	-	1	2	1	(1)	X	X	X	X	X
Macquarie Image	-	(1)	-	1	-	-	1*	1	(1)	-	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
Analysis possible	No	No	No	No	No	No	Yes	?	Yes	Yes	Yes	Yes	Yes		Yes	"	Yes	?	Yes	No	?	No	No	?	No	?

Symbols used:

* Data from next period used also

" Values from previous period re-used; or analysis carried over

X unavailable

( ) low quality usefulness

? Analysis is possible for part of the area; or only a speculative analysis is possible

A maximum of 48 NOAA (or GMS) values are possible, each taken here as being the average for a 1° x 1° square.

In February and March 1985, satellite telex information and BBXX were received but were undated, and could not be used.

ACKNOWLEDGMENTS

This memorandum was prepared for Dr P.J. Mulhearn of RANRL. Satellite imagery used in the analyses was supplied by Dr D. Myers of the Western Australian Institute of Technology. Naval Weather Centre Nowra supplied ship and satellite observations received over the Global Telecommunications System.

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APPENDIX A Data Examples

A.1 NOAA Global SST Observations

Global sea surface temperature observations are obtained daily from the polar-orbiting satellite's multichannel AVHRR sensor. The model used in obtaining these temperatures is the fully automated computer procedure GOSSTCOMP (Global Operational Sea Surface Temperature Computation). The derived observations are stored on computer disk.

There are a number of data bases available for access:

(1) Current Day Observation File - contains SST observations obtained during the previous 36 hours. This file is updated every eight hours, and contains the most current data. This is the file accessed by the National Weather Service to produce a merged satellite/ship SST product. Selected observations from this file are transmitted daily by teletype on the GTS (Global Telecommunication System).

(2) 7-day Observation File - contains all SST observations obtained during the previous 7 days. This file is updated once/day around 0100 local time. This is the file archived weekly with the National Climatic Center.

(3) 100km Analyzed Field File - contains a map of satellite SST's analyzed to a grid with gridpoints at 1° latitude/longitude intersections. This field is analyzed daily using all the satellite SST observations obtained during the previous 24 hours. This is the field displayed weekly on the GOSSTCOMP charts mailed to Australia.

See Table II for examples and Table III for decoding. The SST values are given for 1° x 1°squares. The telexes do not show month or year.

APPENDIX A

A.2 GMS SST Values

These are also received via the GTS. They originate from the Japan Meteorological Bureau. The coding is as for NOAA.

A.3 Ship Observations of SST

These are received via telex. An example and decoding is shown in Table IV. Latitude and longitude are specified to tenths of a degree. Month and year are not given, only the date.

```
TSXS17 KWBC 251600
YYDD  25100 230//
 444  76402 01102 06094
 444  76601 45084
 444  76701 13083
 444  75064 35110 49106 05134 18124
 444  75103 50106 54106 77098 20116 33114 11116 24120 25122
 444  75307 68116 33120 35122 48124 01134 16134 18140
 444  75409 31102 92100 95094 51112 63114 40124 42120 01138 05148
 444  75604 46150 38154 16148 13170
 444  75712 86104 51136 53126 55120 57128 42158 44142 45142 38146
      00172 16156 19173
 444  74011 94132 96138 97138 65164 68158 33168 35170 38188 13190
      15198 08195
 444  74108 91150 93146 56178 68156 41170 43200 13220 25218
 444  74203 70152 49196 28198
 444  74210 93142 95146 88150 60166 63166 65162 68158 41196 33188
      20196
 444  74402 81144 95154
 444  74508 77178 66194 68196 35226 38210 13264 15242 09216
 444  74512 95164 86164 98170 54190 66186 43194 45206 38192 10216
      04208 15212 08214
 444  74709 91166 98178 60198 66178 68182 40196 46190 48186 09198
 444  73009 93210 89202 66216 68214 41232 43224 48226 10246 08250
 444  73108 90202 93230 60216 72240 40234 23258 10250 03276
```

Data for the West Australian area begins with 721 and 731.

Table II. Teletype Message of Global Sea Surface Temperature Observations. See Tables III(a), III(b) for decoding.

(First l..

```
TSXXii
   TS -          . designator : Satellite SST observations
   XX -          .eographical designator
     (a) .N - Northern Hemisphere
     (b) XS - Southern Hemisphere
     (c) XX - Unspecified area
   ii -          Number of bulletin (i1 i2)
     (a) i1 - Bulletin number within a given octant
     (b) i2 - Global octant
KWBC -           Indicator of originating office
YY -             Day of month
GG -             Hour of day
99 -             Minutes of hour
```

(Second line)

```
YYDD   25100   230//
   YY -          SATOB code designator
   DD -          Indicator of surface data
   25 -          Day of month
   10 -          Observation time in hours GMT
    0 -          Tens of minutes of the hour
    2 -          Country of origin (United States = 2)(Japan = 1)
   30 -          Satellite identifier (30 = TIROS-N;
                                       31 = NOAA-6;
                                       32 = NOAA-7; etc.)
```

(Third line)

```
444  76402 01102 06094
  444 -          Indicator of new 10° latitude/longitude square
    7 -          Global octant
    6 -          10° latitude square of observation (6 = 60° square)
    4 -          10° longitude square of observation
                     (4 = 140° or 40° square)
   02 -          Number of observations in the 10° square
```

(Each following group)

```
    0 -          Degrees of latitude from 10° square origin
    1 -          Degree deviation in longitude from 10° square origin
  102 -          Sea surface temperature in degrees Celcius * 10
```

Table III(a) Key to Global Sea Surface Temperature Teletype Message

TABLE III(b)

BULLETIN NUMBERING SCHEME FOR SATOB (SST OBSERVATIONS)

180W 90W 0 90E 180E

OCTANT	1	0	3	2	
90N					NORTHERN HEMISPHERE
	N11	N10	N13	N12	
	N21	N20	N23	N22	
	N31	N30	N33	N32	
	N41	N40	N43	N42	
0					
	S16	S15	S18	S17	SOUTHERN HEMISPHERE
	S26	S25	S28	S27	
	S36	S35	S38	S37	
	S46	S45	S48	S47	
90S					
OCTANT	6	5	8	7	

This table illustrates the relationship of the GTS bulletin numbering scheme and the geographical coverage of the data within the bulletin for sea surface observations coded in the SATOB form. The SST bulletin heading will contain as the first character grouping TSX plus the three-character code shown in the table. For example, TSXN13 will contain the first bulletin SST observations in the SATOB code from the area 0-90°E longitude and 0-90°N latitude.

Table III(b) Bulletin Numbering Scheme for SST observations.

JN0575
D23006

DDHA3
06123

Latitude 30.7

Quadrant 3

Longitude 104.7

```
NNNNNRFC NSYA NCBF NCBA NNWN NWMR NRIR NBKA 876DPERTHRADIO 0612417
BBXX
VPBW 06123 99307 31047 42097 82414 10150 2008/ 40170 53020
702// 88/// 22263 00155 2//05 326// 40308=
```

Start

SST (15.5°C)

Table IV. Example of and decoding of ship telex observations of SST (BBXX coding).

APPENDIX B

Recognition Points for Satellite Imagery

The WAIT images are obtained as ungridded slides. The slide images were projected onto a screen and traced to give a picture roughly A3 size. Diagrams of the satellite swathe on the slides were found to be not accurate enough for defining latitude-longitude lines.

Parallel latitude and longitude lines were therefore drawn in the sequence shown in Fig.16, using recognizable features of the coast as control points. Three reference lines of longitude and four reference lines of latitude can be constructed: for 113, 114, 115°E and 22, 26, 33°30', and 35°S. The spacing between latitude lines increases southwards on the projection shown. Latitude lines were assumed to be perpendicular to longitude lines. The method appeared to be successful, there apparently being little distortion in the images used. Size scales were different from image to image.

The Macquarie GMS images show latitude and longitude lines at 20 degree intervals, so that a grid could be drawn for all images.

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16. Abstract

Attempts made at real time oceanographic analyses for the south-western Australian area are shown diagrammatically in the form of contour maps, and results discussed. The period is July 1984 to August 1985. It is concluded that with present data sources useful sea surface temperature analyses should be possible in late spring, summer and perhaps early autumn, but not in winter, when cloud coverage severely hinders satellite data acquisition. Subsurface analyses were not possible, almost all data being for the sea surface.

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